NUMBER 113 SEPTEMBER 2007

Quaternary Newsletter

A publication of the
Quaternary Research Association

QUATERNARY NEWSLETTER

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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects, etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant numbers are 1st January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue**.

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (500 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps format. Quaternary Research Fund and New Research Workers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects.

Argraff/Printed by:
Gwasg Ffrancon Press
BETHESDA
Gwynedd, North Wales
Tel: 01248 601669 Fax: 01248 602634.

COVER PHOTOGRAPH
Delegates of the QRA field meeting to the Brecon Beacons at Traeth Mawr (Photo: Tim Mighall)

PRESIDENT'S ANNOUNCEMENTS

INTERNATIONAL UNION FOR QUATERNARY RESEARCH (INQUA): A REPORT ON THE XVIITH INTERNATIONAL CONGRESS, 2007 AND ON NEW DEVELOPMENTS

Introduction

This article reports some important developments approved during the XVIIth INQUA International Congress held in Cairns, Australia between 28th July and 3rd August, 2007. It also records some key roles played by QRA members in the congress and in associated INQUA activities. Important changes affecting INQUA's organisation and structure were introduced during the XVIth INQUA Congress held in Reno, Nevada in 2003 and these were reinforced by the INQUA's International Council during the most recent congress. The primary purposes of this note, therefore, are (a) to provide QRA members with an up-date on the new developments and some indication of the rationale behind the changes, and (b) to encourage members to become more closely involved in INQUA's core activities. For details on how INQUA was organised and structured prior to 2003, readers are referred to the excellent short summary in Walker and Boulton (1999). One important recent change in INQUA's international status was its election to full membership of ICSU (the International Council for Science) in October 2005. This enables INQUA to have more influence in the developing global scientific agenda. Of course, as we all know, Quaternary records are the most important when it comes to placing current concerns about future global change in a longer term context. INQUA now has a better opportunity to promulgate this message in the international forum. INQUA's executive decisions and all of its formal activities are governed by Statutes which are subject to periodic review and approval by the International Council. The statutes and further details on INQUA in general can be found on the INQUA web site at http://www.inqua.tcd.ie/.

Membership of INQUA

Policy proposals concerning the organisation and governance of INQUA are formulated by the INQUA Executive Committee (see below). These must be submitted to the International Council (IC) of INQUA for consideration and approval. The IC consists of the national representatives of all the member countries or regions of INQUA. For the UK, the national representative is the QRA President in post at the time of the congress, or his nominated representative. Each national representative is permitted one vote on the IC, but only the representatives of member countries or regions not in default of annual membership fees are eligible to vote. The member countries and regions approved at the 2007 IC meetings are listed in Table 1. One of the major roles of the IC is to receive and vote on nominations for membership of the INQUA Executive Committee to serve for the subsequent inter-congress period.

Table 1: Member countries and regions of INQUA, 2007

Argentina	Finland	Poland
Australia	France	Portugal
Austria	Germany	Republic of Korea
Belgium	Hungary	Russia
Ireland	India	Serbia
Brazil	Ireland	South Africa
Canada	Israel	South America
China	Italy	Spain
Chinese Taipei	Japan	Sweden
Czech Republic	Latvia	Switzerland
Denmark	Lithuania	The Netherlands
East Africa	New Zealand	United Kingdom
Estonia	Norway	USA

Membership of the INQUA Executive Committee

The INQUA Executive Committee (EC) has the responsibility of governing INQUA's core activities, financial matters and appropriate links with other international scientific bodies during the relevant inter-congress period. It also has a planning role, looking to INQUA's future engagement with the international science agenda, while reviewing the organisation's formal statutes to ensure that they accord with evolving policies and procedures. The EC must submit to the IC full reports on its actions, policy proposals and financial transactions undertaken during the inter-congress period in which it held office; the reports are submitted to the IC for inspection at the congress meeting which occurs during the fourth and final year of the EC's term of office. The committee members elected to hold office for the 2007-2011 inter-congress period are listed in Table 2. Note that the President who held post during the preceding inter-congress period automatically becomes a member of the subsequent EC to serve for a further inter-congress period. This provides continuity with respect to decisions and actions taken by the preceding EC and an expert steer on any outstanding issues requiring the new EC's prompt attention.

Table 2: INQUA Executive Committee elected to serve for the 2007-11 inter-congress period

President:	Allan Chivas, Wollongong, Australia
Secretary-General:	Peter Coxon, Dublin, Ireland
Treasurer:	Marie-France Loutre, Louvain, Belgium
Vice-Presidents (4):	Allan Ashworth, North Dakota, USA
	Margaret Avery, Cape Town, South Africa
	John Lowe, London, UK
	Koji Okumura, Hiroshima, Japan
Past President:	John Clague, Vancouver, Canada

The General Assembly

The IC reports its decisions and recommendations to the INQUA General Assembly (GA) for final ratification. The GA comprises all delegates who attend the INQUA Congress. There are usually two meetings of the GA. The first is held on the opening day of the congress when key issues that are to be deliberated upon by the IC are introduced, providing delegates with advance notice and hence the opportunity to express their views to their IC national representatives. The more important GA meeting occurs on the final day of the congress, when the IC's proposals for the next inter-congress period are announced, and endorsement by the GA is sought. While it is unusual for the GA to oppose the recommendations tabled by the IC, the Statutes do allow for this possibility in order to register any ground-swell of opinion that diverges from the majority vote taken by the IC. It is therefore an important and essential part of the approval process, providing a gauge of the wider support among the INQUA body.

QRA input into the IC

It has become a regular practice during INQUA congresses for the UK national representative on the IC to arrange an open meeting to which all UK delegates in attendance at the congress are invited. The purpose of the meeting is to allow wide debate on the major issues under consideration by the IC, and thereby to provide the UK National Representative with a QRA steer, which is especially important for matters that require a vote by the IC. This practice was also adopted at the Cairns Congress; a notice was posted on the main notice-board at the Cairns Convention Centre on 29th July, inviting all QRA members in attendance at the congress to a meeting held on 1st August, 2007. Table 3 lists all those who attended that meeting; we extend our sincere thanks to all named for giving up their limited free time and for providing clear and helpful guidance on strategic voting by the national representative at subsequent IC meetings.

Table 3: QRA members who attended the meeting held on 1st August, 2007 to provide advice to the UK national representative on matters to be considered by the INQUA International Council

Judy Allen, Durham University
Mark Bateman, Sheffield University
Tom Bradwell, BGS Edinburgh
Chris Caseldine, Exeter University
Richard Chiverrell, Liverpool University
Chris Clark, Sheffield University
Siwan Davies, University of Wales Swansea
David Evans, Durham University
Callum Firth, Brighton University
Cynthia Froyd, Oxford University
Jane Hart, Southampton University
Anna Hughes, Sheffield University
Pete Langdon, Southampton Univertsity
Jonathan Lee, BGS Keyworth
Suzanne Leroy, Brunel University
Fraser Mitchell, Trinity College Dublin
Neil Loader, University of Wales Swansea
John Lowe, Royal Holloway, University of London (in Chair; UK Nat. Rep.)
Jasper Knight, Exeter University
Alison Macleod, Royal Holloway, University of London
Bob McCulloch, Stirling University
Barbara Maher, Lancaster University
Fabienne Marret, Liverpool University
Frank Mayle, Edinburgh University
Sarah Metcalfe, Nottingham University
Adrian Palmer, Royal Holloway, University of London
Kathryn Rose, Southampton University
Sean Pyne-O'Donnell, Royal Holloway, University of London
Dave Roberts, Durham University
Iain Robertson, University of Wales Swansea
Jim Rose, Royal Holloway, University of London
Martin Siegert, Edinburgh University
Chris Stringer, Natural History Museum London
David Sugden, Edinburgh University
Phil Teasdale, Brighton University
Nicki Whitehouse, Queen's University Belfast

INQUA Commissions

INQUA sponsors a programme of international collaborative research projects in Quaternary science. These are promoted and managed by INQUA

Commissions. Up until 2003, INQUA recognised 12 commissions which addressed a diverse range of topics (Walker & Boulton, 1999). At the Reno Congress in 2003, however, the number of commissions was reduced to five, each with a wider-ranging scientific brief and a remit to encourage greater cohesion and inter-disciplinary co-operation. This policy was endorsed by the IC at the 2007 Cairns congress.

Commissions are managed by a Commission President, one or more Vice-Presidents and a Secretary. Several commissions have also created Advisory Councils, consisting of a number of experts drawn from the relevant international scientific community. The Advisory Councils represent the spectrum of interest within the commissions and provide the commission officers with guidance on the commissions' activities and plans.

The Commissions and corresponding commission officers approved by the IC to serve over the next inter-congress period are listed in Table 4. More information on each commission can be found on the INQUA web site.

Table 4: Commissions and commission officers approved for the 07-11 inter-congress period

Commissions	Commission Officers
Coastal and Marine Processes (CMP)	President: C. Baeteman, Geological Survey Belgium Vice-president: Y. Yokoyama, Tokyo, Japan Secretary: C. Firth, Brighton, UK
Palaeoclimate (PALCOM)	President: S.Harrison, Bristol, UK Vice-President: P.Kershaw, Monash, Australia Secretary: J.Shulmeister, Canterbury, NZ
Palaeoecology and Human Evolution (PAHE)	President: G.Haynes, Reno, USA Vice-President: L. Borrero, Buenos Aires, Argentina Vice-President: N. Whitehouse, Belfast, UK Secretary: D. Taylor, Dublin, Ireland
Stratigraphy and Chronology (SACCOM)	President: B.Pillans, Canberra, Australia Vice-President: V. Hall, Belfast, UK Secretary: T. van Kolfschoten, Leiden, The Netherlands
Terrestrial Processes, Deposits and History (TERPRO)	President: J. Teller, Manitoba, Canada Vice-President: to be elected Vice-President: to be elected Secretary: to be elected

Remit of Commissions

Commissions initiate, promote and manage INQUA's international collaborative scientific activities. Prior to 2007, some Commissions recognised *Sub-commissions*, which provided a focus on very specific themes within INQUA's sphere of interest. All commissions also supported projects, which to some extent fulfilled a function similar to Sub-commissions. Partly because of a blurring of the distinction between sub-commissions and projects, and also because of lack of clarity as to whether sub-commissions could be regarded as permanent entities or not, the structure of INQUA's core activities has been revised, and is summarised in Figure 1.

The IC at the 2007 Cairns congress resolved the following:

- that the use of the term 'sub-commission' be discontinued within INQUA's structure and formal reports
- that Commissions will initiate and nurture *International Focus Groups*, which are non-permanent collaborative actions designed to address scientific themes and issues of wide international significance; the duration of IFGs will depend upon their track records and how well they continue to meet key scientific needs
- *Projects* are smaller-scale activities that are focused on very specific aims and objectives and which contribute in strategic ways to the wider aims of one or more IFGs.

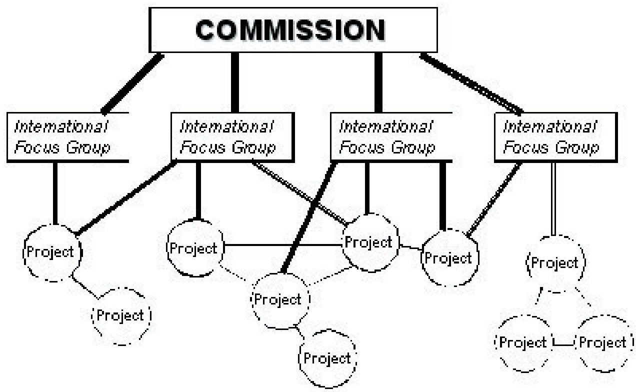

Figure 1: New structure of INQUA's core activities, endorsed by the International Council and General Assembly of INQUA at the XVIIth Congress, Cairns, Australia, 2007 (after Gary Haynes, President of PAHE Commission)

This makes for a clearer hierarchical structure and terminology for the orchestration and description of INQUA's core activities. Inter-Commission collaboration in IFGs and projects is encouraged by the INQUA executive, as is co-operative arrangements with other international scientific bodies such as IGCP, PAGES and IGBP.

Achievements of QRA members at the Cairns INQUA Congress

The QRA was extremely well represented at the Cairns congress, with UK scientists probably forming the biggest national complement with the exception of that of the host nation. The volume of abstracts of the congress proceedings (Chappell et al., 2007) gives testimony to the important role played by QRA delegates, as reflected in the impressive number of papers and posters in which they were involved. A number of members also played important roles in the organisation and chairing of thematic sessions.

In addition to the elections of QRA members to various INQUA committees, reported above, it is indeed a great pleasure to report the following individual achievements :

- Professors **Geoff Boulton** (Edinburgh) and **Jan Mangerud** (Bergen) were both elected to Honorary Membership of INQUA, in recognition of their distinguished contributions to Quaternary science
- Professor **Chris Turney** (until recently based at Wollongong, Australia, but now at Exeter University) was awarded the inaugural *Sir Nicholas Shackleton Prize* for the most outstanding young Quaternary scientist
- Professor **Chris Stringer** (NHM and Visiting Professor at Royal Holloway) gave a much acclaimed Plenary Lecture on the origins and dispersal of pre-modern hominids
- **Alison Macleod** (NERC-funded PhD student at Royal Holloway) won one of the prizes awarded to research students for best poster presentations
- Professor **Jim Rose** (Royal Holloway) was warmly congratulated by many delegates for the outstanding achievement of raising the impact factor of *Quaternary Science Reviews* to 4.1, third highest in the *Geology Multidisciplinary* category of journals, and top in the *Geography* category
- Professor **Scott Elias** (Royal Holloway) was also warmly congratulated on the publication of the *Encyclopedia of Quaternary Science* (Elias, 2006) which has attracted wide acclaim, including the award of the *Mary B. Ansari Best Reference Work* by the *Geoscience Information Society (GSIS),* which will be presented at the 2007 annual meeting of the Geological Society of America.

On behalf of the QRA membership, we offer all named our warmest congratulations.

Edinburgh bid for INQUA 2011

A bid was submitted to the IC at the Cairns Congress to bring the next (XVIIIth) INQUA Congress to Edinburgh in 2011. The proposal was a joint venture between the QRA and the Quaternary associations of Denmark, Iceland, Ireland and Norway. Representatives of each of the associations helped to prepare the bid, which was co-ordinated by David Sugden (Edinburgh University) and Tom Bradwell (BGS, Edinburgh) and David presented the case at the IC meeting. The bid was prepared and presented in an extremely professional manner and was manifestly attractive. It seemed to have widespread support among INQUA delegates in advance of the crucial meeting of the IC which decided the issue by ballot of its members. Sadly, the Edinburgh bid was out-voted by the slender margin of a single vote in favour of a rival bid from Bern, Switzerland. On behalf of the QRA membership, we offer our commiserations and sincere thanks to all those who helped in the bid preparations, but especially to David and Tom.

Towards the XVIIIth INQUA Congress in Bern, Switzerland in 2011

Collectively, QRA members made a significant impact at the Cairns Congress. Attention now turns to preparing the ground for enabling members to make an even bigger impact in Bern in 2011. Towards that end, the QRA Executive Committee is developing a strategy for significantly enhancing the funds to be made available in 2011 to provide financial support for its members who wish to attend the XVIIIth INQUA Congress. Members are also encouraged to become more directly involved in INQUA's activities. Ideas for new IFGs and projects are welcomed by the INQUA Commission officers, and can come from the 'floor'. If members have good ideas for topical and important IFGs or for strategic projects which address the agendas of existing IFGs, they should communicate those to INQUA officers. There is a limit to how many projects INQUA can support financially, but for some projects it may be sufficient to receive the status of formal INQUA recognition, which may help to secure funds from other organisations. INQUA will introduce the practice of according formal recognition on new IFGs and projects during the present inter-congress period. Like the QRA, INQUA is a 'bottom-up' organisation; it relies for its existence and international esteem on the vitality, scientific acumen and co-operative interactions of its members. Members who have not already done so are encouraged to familiarise themselves with the current commission structures and the range of IFGs and projects they currently support. The easiest way to become involved is to sign up as a Corresponding Member of a Commission by contacting the relevant Commission Secretary or to contact the co-ordinators of those existing IFGs and projects to which members consider they can make a contribution.

References

Chappell J.C. et al. (eds.) (2007). XVII INQUA Congress – 'The Tropics: Heat Engine of the Quaternary' (volume of abstracts). *Quaternary International* vol. 167-168 Supplement, 486 pp.

Elias, S.A. (ed.). (2006). *Encyclopaedia of Quaternary Science*. Elsevier, Amsterdam, 4 volumes.

Walker, M.J.C. and Boulton, G.S. (1999). International Union for Quaternary Research (INQUA) and the Quaternary Research Association. *Quaternary Newsletter* 89, 10-18.

John Lowe (Royal Holloway, University of London)
and Pete Coxon (Trinity College, University of Dublin)

ARTICLES

EVIDENCE FOR LOCH LOMOND STADIAL ICE CAP GLACIATION OF THE BEINN DEARG MASSIF, NORTHERN SCOTLAND

Andrew Finlayson and Tom Bradwell

Introduction

Accurately establishing the configuration of former ice masses is extremely important in order to make useful inferences regarding palaeoclimate. Whether or not former glaciers existed as independent masses or formed part of a larger icefield or ice cap complex has important implications for reconstructed equilibrium line altitudes (ELAs), from which palaeoclimatic inferences are derived (Rea *et al.,* 1998; Rea and Evans, 2003). Previous research suggests that during the Loch Lomond Stadial (Younger Dryas) (*c*. 12 900 – 11 500 cal. yr BP), the Beinn Dearg massif in the northern Scottish Highlands supported thirteen independent glaciers, all but four occupying its western side (Sissons, 1977) (Figure 1). In this paper we present new geomorphological evidence to suggest that a Loch Lomond Stadial glacier also occupied Glen Alladale, on the north-east margin of the Beinn Dearg massif, and propose that this glacier was part of an ice cap system which probably included a number of glaciers previously mapped as independent masses. Consequently, we suggest that Sissons (1977) considerably underestimated the volume of ice that existed in the area during the Loch Lomond Stadial.

The Beinn Dearg massif forms a broad, upland plateau, exceeding 300 km^2 in area. Approximately 150 km^2 of the massif lies above 600 m OD, with the highest point, Beinn Dearg, rising to an altitude of 1084 m. The plateau is dissected by one major east-west trending through valley, and a number of steep-sided corries and valleys radiate out towards the massif margins. The bedrock is composed predominantly of Neoproterozoic psammites and pelites, with several intrusions of gneissose granite occurring to the east (British Geological Survey, 2004).

Glacial landforms in the area were first documented by Officers of the Geological Survey who proposed three distinct phases of glaciation, each progressively smaller in extent (Peach *et al.,* 1912, 1913). During their third, final glacial stage, Peach *et al*. (1913, p.95) envisaged a situation where “each prominent mass of high ground became an independent ice-centre, and nourished its own glaciers, which followed the natural trend of the valleys”. Later investigation

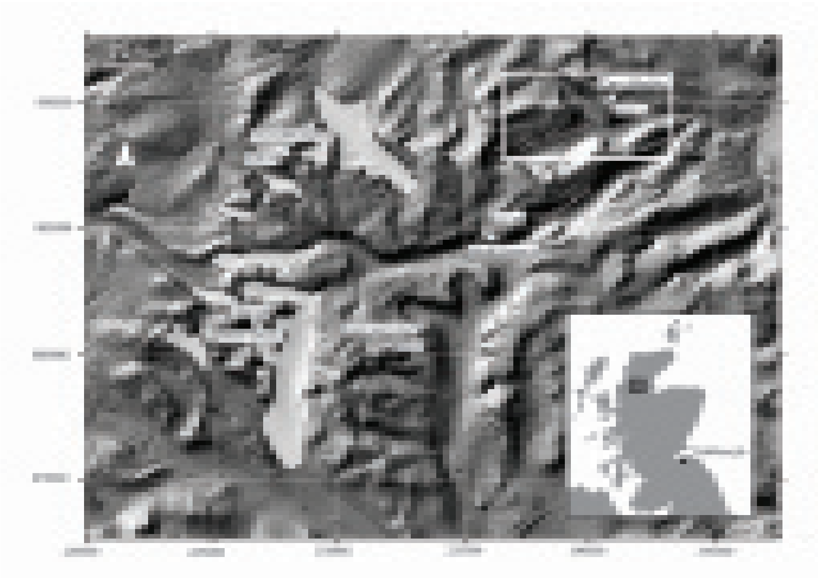

Figure 1. Location of Beinn Dearg massif. Glen Alladale is located within the white boundary. Former glaciers are redrawn from Sissons (1977). NEXTMap hill-shaded surface model built from Intermap technologies digital elevation data.

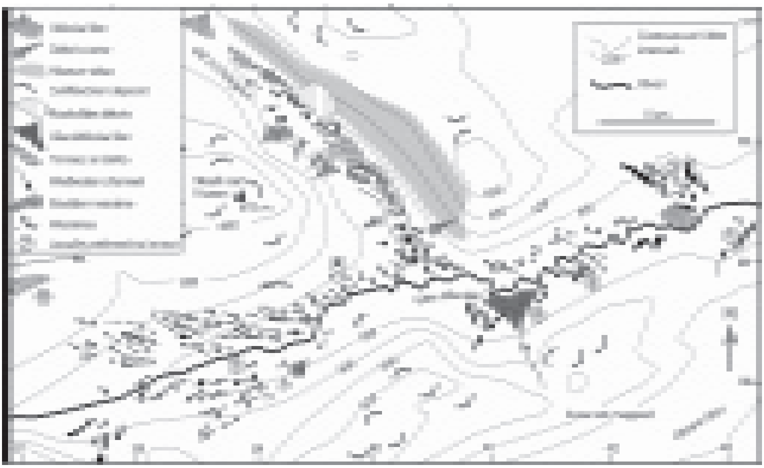

Figure 2. Geomorphology of Glen Alladale.

concerning the most recent glacial phase in the Beinn Dearg area was carried out by Sissons (1977), during the first attempt to systematically map the extent of Loch Lomond Stadial glaciers in the northern mainland of Scotland. Sissons (1977) reconstructed thirteen independent glaciers within the Beinn Dearg massif. However, due to the large area covered in his study, he noted that not all sites could be visited and that additional glaciers may also have existed. More recently, it has been suggested that an icefield developed over the Beinn Dearg massif (Ballantyne, 1997), although no palaeoglaciological reconstruction has yet been published.

Methods

The British Geological Survey (BGS) is currently undertaking a 10-year project to revise the bedrock and superficial geological maps of the NW Highlands of Scotland. Detailed mapping of the landforms and sediments in the vicinity of Glen Alladale was carried out in April and May 2006 as part of the resurvey of Scotland Sheet 102W (Glen Oykel). Field mapping was carried out at a scale of 1:25 000 during which natural sections were cleaned and logged. 1:24 000 black and white stereo aerial photographs and NEXTMap hill-shaded digital surface models were consulted prior to, and following, field surveying.

Landforms in Glen Alladale

The results of the field mapping reveal a complex landform assemblage (Figure 2). A sharp-crested moraine ridge and adjacent meltwater channel extend from the valley floor up to the slope crest on the southern side of Glen Alladale (1). This ridge can be traced round to a suite of large end moraines on the northern side of the valley (2). Up-valley a series of *c*. 5 to 10 m high moraine ridges run almost perpendicular to the valley axis (3). A large fan (4) composed of stratified boulder and cobble gravel is located below a col and meltwater channel linking Glen Alladale with Gleann Mor to the south.

A complex of boulder-strewn moraine ridges (Figure 3) occupies much of the western side of the valley of Allt á Chlaiginn which joins Glen Alladale from the north (5). Rare exposures in these ridges reveal sandy matrix-supported diamicton with poorly sorted, angular to subrounded clasts up to 1 m in diameter. The moraine complex is incised by two meltwater channels, up to 10 m deep and 30 m wide, which originate near a terrace feature and continue down-valley towards Glen Alladale. The floor of one channel is presently dry while the other contains the relatively small Allt á Chlaiginn. Thick talus covers much of the north-eastern slopes of the Allt á Chlaiginn valley, while the south-western slopes support gullied till.

In western Glen Alladale, a series of small, closely spaced moraine ridges occur on the northern side of the valley (6). These moraines continue up-valley into a system of valley-symmetrical mounds and ridges trending obliquely down

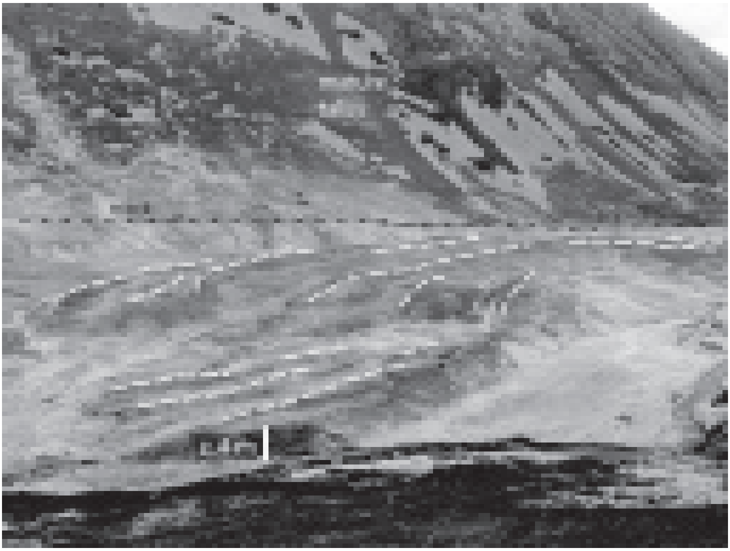

Figure 3. Moraine ridges on the western side of Allt á Chlaiginn. Dashed white line indicates individual ridges. View looking east from the eastern side of Meall nam Fuaran.

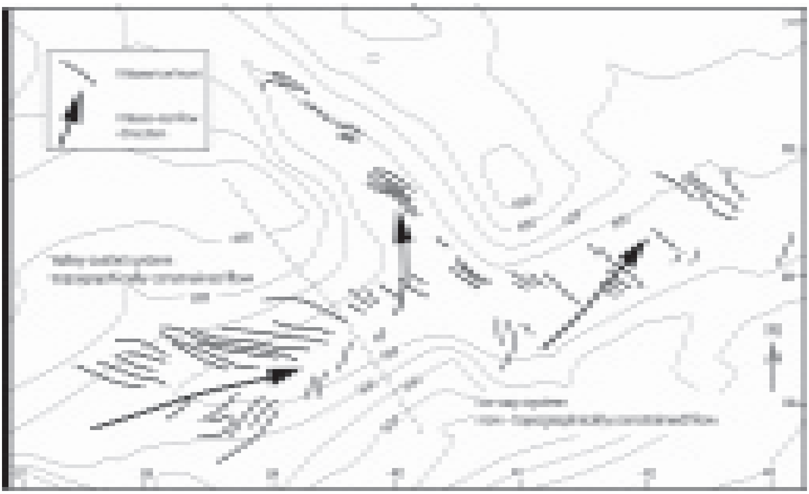

Figure 4. Suggested pattern of ice retreat in Glen Alladale based on palaeo-ice fronts inferred from moraine distribution. The dashed line indicates the transition from an ice cap system to a valley outlet system.

the valley sides (7). On the high ground near the head of the glen a prominent boulder moraine (8) lies adjacent to a well developed meltwater channel.

Interpretation

The cross-valley moraines (2 and 3) in the eastern half of Glen Alladale and the complex of moraines in the valley of Allt á Chlaiginn (5) mark former marginal positions of an ice mass that flowed towards the north-north-east and north-east. The moraines and terraces in the Allt á Chlaiginn valley are inferred to relate to ice that was not entirely confined by topography, pushing north-eastwards over the shoulder of Meall nam Fuaran and up to 2 km into the Allt á Chlaiginn valley. The thick, debris-flow incised till on the south-western slopes of this valley starkly contrasts with the mature talus occupying the north-eastern slopes. This may reflect cavity infilling as ice flowed obliquely into the valley from the southwest, while the north-eastern slopes remained ice free. Ice pushing into the Allt á Chlaiginn valley may also have dammed a lake forming the terrace or delta features which lie up-valley from individual clusters of moraine ridges. Water from such a lake could have ultimately drained via the two large meltwater channels which continue down-valley from the terraces. Following ice retreat from lower Glen Alladale, a large glaciofluvial fan (4) accumulated. Presently no obvious source exists for the fan, and we suggest that it was fed by ice which once flowed over the col from Gleann Mor to the south.

The asymmetrical distribution of till and morainic deposits in the valley and evidence for oblique cross-valley ice flow are consistent with elements seen in ice cap landsystems (Golledge, 2007). It is suggested that ice flowing into Glen Alladale was part of an overall domed configuration, possibly centred in the vicinity of Meall Dionach to the south-west. The boulder moraine (8) at c. 600 m may represent a lateral limit of the former ice cap at this stage.

The transition from perpendicular cross-valley moraines predominantly on the northern side of Glen Alladale, to symmetrical valley-oblique ‘hummocky moraines’ (7) may represent the disintegration of the ice cap system to a mountain icefield complex, for which Glen Alladale was an outlet (Figure 4). Early phase ice flow was, to an extent, governed by the surface slope of the ice cap which overrode some topographic obstructions. Thinning of this ice, however, allowed topography to become more dominant, resulting in more easterly ice flow in Glen Alladale during the latter stage.

Accurately establishing when this ice cap system existed is of particular importance since a Loch Lomond Stadial age would require considerable revision to Sissons’ (1977) reconstruction. At present no direct dating evidence has been obtained within Glen Alladale, however, several lines of mophostratigraphic evidence suggest that the glacier may indeed have existed during the Loch Lomond Stadial.

Firstly, 'hummocky moraine' is abundant in Glen Alladale, particularly at the western end. Although this landform is not totally exclusive to areas occupied by Loch Lomond Stadial glaciers (Clapperton *et al.,* 1975; Everest and Kubik, 2006), it is frequently observed within limits that have been identified from other evidence (e.g. Walker *et al.,* 1988; Ballantyne, 1989; Ballantyne, 2002). Secondly, the distribution of mature talus outside the moraines in the Allt á Chlaiginn valley suggests that a period occurred when the south-western slopes were occupied by ice and the north-eastern slopes were exposed to periglacial conditions. As the last period of intense periglacial activity in upland Britain was the Loch Lomond Stadial (Ballantyne and Harris, 1994), this age may be suggested for the moraine formation. Thirdly, the eastern end of Glen Alladale displays a suite of obvious, sharp-crested end moraines, which are notably larger that those further up valley. This landform characteristic has been suggested by Lukas (2006) to be typical of the maximum limits of former Loch Lomond Stadial glaciers elsewhere in NW Scotland. Finally, previous studies have demonstrated that while a number of river terraces occur outside former Loch Lomond Stadial ice limits, often only one exists above the present floodplain within those limits (Sissons, 1974; Benn and Ballantyne, 2005; Lukas, 2006). In Glen Alladale, only one terrace occurs above the present floodplain.

Implications

The new evidence suggests the former existence of a local ice cap which extended into Glen Alladale, and was possibly centred in the vicinity of Meall Dionach to the south-west. If this ice mass existed during the Loch Lomond Stadial, as indicated by the morphostratigraphy, it implies that substantially more ice existed over the Beinn Dearg massif than previously thought.

A quick estimation of the ELA in Glen Alladale can be obtained using the toe-to-headwall-altitude ratio (THAR) method (Meierding, 1982) (ELA = lowest elevation of glacier + vertical range x ratio). This method yields an ELA of 450 m (THAR = 0.4), however, it does not account for any contribution from plateau ice and must be seen as a minimum value. Lateral moraines at altitudes of *c*. 500 m in Glen Alladale and the boulder moraine (8) at *c*. 600 m suggest higher ELAs, based on the maximum altitude of lateral moraine method (e.g. Andrews, 1975), and are consistent with ice flowing over high ground into Glen Alladale.

The ELA values lie c. 100 - 300 m higher than preliminary estimates (324 m) for the Ben Hee ice mass (Lukas, 2005) 40 km to the north. This could reflect reduced precipitation owing to the Beinn Dearg massif's position further inland, a greater cover of plateau ice over the Beinn Dearg massif, or a combination of both.

Given that approximately 150 km^2 of broad undulating plateau lies above the highest ELA estimate (*c*. 600 m) for Glen Alladale, it seems possible that the Beinn Dearg massif could have supported a >100 km^2 ice cap or icefield, which probably included a number of glaciers previously mapped as independent masses. Such a configuration echoes the views of Peach *et al*. (1913) concerning the final stage of glaciation in the area and has significant implications for modelling palaeoclimate.

Further work is being carried out to accurately establish the timing of events in Glen Alladale. Boulders from the glen have been sampled for cosmogenic dating – part of a wider study into the overall dimensions and dynamics of the last glaciers in the Beinn Dearg area.

Acknowledgements

We thank BGS colleagues: Nick Golledge, Jon Merritt and Chris Thomas for constructive comments on earlier versions of the manuscript. Alastair Gemmell and Stephan Harrison provided valuable reviews. This paper is published with the permission of the Executive Director of BGS (NERC).

References

Andrews, J.T. (1975). *Glacial Systems: an approach to glaciers and their environments*. Duxbury Press, North Scituate, MA.

Ballantyne, C.K. (1989). The Loch Lomond Advance on the Isle of Skye, Scotland: glacier reconstruction and palaeoclimatic implications. *Journal of Quaternary Science,* 4, 95-108.

Ballantyne, C.K. (1997). Periglacial trimlines in the Scottish Highlands. *Quaternary International,* 38/39, 119–136.

Ballantyne, C.K. (2002). The Loch Lomond Readvance on the Isle of Mull, Scotland: glacier reconstruction and palaeoclimatic implications. *Journal of Quaternary Science,* 17, 759-771.

Ballantyne, C.K. and Harris, C. (1994). *The Periglaciation of Great Britian*. Cambridge University Press, Cambridge.

Benn, D.I. and Ballantyne, C.K. (2005). Palaeoclimatic reconstruction from Loch Lomond Readvance glaciers in the West Drumochter Hills, Scotland. *Journal of Quaternary Science,* 20, 577-592.

British Geological Survey. (2004). *Ben Wyvis. Scotland Sheet 93W. Bedrock and Superficial Deposits. 1:50 000*. Keyworth, Nottingham.Clapperton, C.M., Gunson, A.R. and Sugden, D.E. 1975. Loch Lomond Readvance in the eastern Cairngorms. *Nature,* 253, 710-712.

Everest, J. and Kubik, P. (2006). The deglaciation of eastern Scotland:

cosmogenic ^{10}Be evidence for a Lateglacial stillstand. *Journal of Quaternary Science,* 21, 95-104.

Golledge, N.R. (2007). An ice cap landsystem for palaeoglaciological reconstructions: characterising the Younger Dryas in western Scotland. *Quaternary Science Reviews,* 26, 213-229.

Lukas, S. (2005). *Younger Dryas moraines in the NW Highlands of Scotland: genesis, significance and potential modern analogues*. Unpublished PhD Thesis, University of St Andrews.

Lukas, S. (2006). Morphostratigraphic principles in glacier reconstruction – a perspective from the British Younger Dryas. *Progress in Physical Geography,* 30, 7 19-736.

Meierding, T.S. (1982). Late Pleistocene glacial equilibrium-line in the Colorado Front Range: a comparison of methods. *Quaternary Research,* 18, 289–310.

Peach, B.N., Gunn, W., Clough, C.T., Hinxman, L.W., Crampton, C.B. and Anderson, E.M. (1912). *The geology of Ben Wyvis, Carn Chuinneag, Inchbae and the surrounding country.* Memoir of the Geological Survey, HMSO

Peach, B.N., Horne, J., Gunn, W., Clough, C.T. and Greenly, E. (1913). *The geology of the Fannich Mountains and the country around upper Loch Maree and Strath Broom*. Memoir of the Geological Survey, HMSO.

Rea, B.R., Whalley, W.B., Evans, D.J.A., Gordon, J.E and McDougall, D.A. (1998). Plateau icefields: geomorphology and dynamics. In: Owen L.A. (ed.) *Mountain Glaciation.* Quaternary Proceedings No. 6, Wiley, Chichester, 35-54.

Rea, B.R. and Evans, D.J.A. (2003). Plateau Icefield Landsystems. In: Evans, D.J.A. (ed.) *Glacial Landsystems*. Arnold, London, 407-431.

Sissons, J.B. (1974). A Late-glacial ice cap on the central Grampians, Scotland. *Transactions of the Institute of British Geographers,* 62, 95-114.

Sissons, J.B. (1977). The Loch Lomond Readvance in the Northern Mainland of Scotland. In Gray, J.M. and Lowe, J.J. (eds) *Studies in the Scottish Lateglacial environment*. Pergamon, Oxford, 45-59.

Walker, M.J.C., Ballantyne, C.K., Lowe, J.J. and Sutherland, D.G. (1988). A reinterpretation of the Lateglacial environmental history of the Isle of Skye, Inner Hebrides, Scotland. *Journal of Quaternary Science,* 3, 135-146.

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COSMOGENIC ISOTOPE ANALYSIS PROVISION IN BRITAIN: THE ROLE OF THE NATURAL ENVIRONMENT RESEARCH COUNCIL COSMOGENIC ISOTOPE ANALYSIS FACILITY STEERING COMMITTEE

Mike Walker, Antony Long, Tony Fallick and Lin Kay

Introduction

The purpose of this paper is to bring to the attention of the Quaternary and Earth Science community the nature of cosmogenic isotope analysis (CIA) provision in the UK, to give an update on recent developments in the cosmogenic isotope analysis service supported by the Natural Environment Research Council (NERC), and to offer guidance to those who might be interested in applying to NERC for CIA support. Our particular aim is to explain to scientists how the Cosmogenic Isotope Analysis Facility Steering Committee operates, and the ways in which applications should be constructed in order to meet the standards required by the Committee in the peer-review process.

NERC-funded Cosmogenic Isotope Analysis provision in Britain

CIA support provided by NERC is underpinned by the Accelerator Mass Spectrometer (AMS) Laboratory in the Scottish Universities Environmental Research Centre (SUERC) at East Kilbride. The Laboratory was established via a NERC grant in 2002 following a successful bid to the Joint Infrastructure Fund (JIF), and is based on a 5 MV National Electrostatics Corporation AMS. Although the machine is also used for ^{14}C dating, it was always intended that a considerable proportion of the beam-time would be allocated to terrestrial cosmogenic nuclides, notably ^{10}Be, ^{26}Al and ^{36}Cl. This was a major development in Quaternary and Earth science research in Britain, for it meant that, for the first time, British scientists would have access to a home-based CIA Facility and, as a consequence, could become more closely engaged with the rapidly expanding field of cosmogenic isotope analysis.

In 2004, the CIAF at SUERC became a NERC Facility. NERC-related provision is the responsibility of the Scientific Services and Facilities Management Team, headed by Dr Lin Kay. Management responsibilities in the East Kilbride Facility, however, lie with SUERC. The CIAF is under the overall direction of Professor Tony Fallick, but the operation of the CIAF is the responsibility of Dr Christoph Schnabel. The CIAF is one of 27 Scientific Services and Facilities run or overseen by NERC, and competes for resources against these facilities. The quality of provision is under regular review by NERC as part of their annual review of services, with the CIAF last being reviewed in 2006. The next review is scheduled for 2009.

Applications for analytical support

All applications for analytical support are peer-reviewed by a Steering Committee which is currently chaired by Professor Mike Walker (University of Wales, Lampeter), but who will be replaced in May 2007 by Professor Antony Long (Durham University). The Steering Committee comprises five appointed members, one of whom is an international panel member (currently Professor John Stone), and four *ex officio* members. The present membership of the Steering Committee (as at 1.3.07) is shown in the following table

Appointed members	
Professor Mike Walker (Chairman to May 2007)	University of Wales, Lampeter
Professor Mike Bickle	University of Cambridge
Professor Antony Long (Chairman from May 2007)	University of Durham
Professor John Stone	University of Washington, USA
Professor Mike Summerfield	University of Edinburgh
Ex officio	
Professor Tony Fallick	SUERC, East Kilbride
Dr Stewart Freeman	SUERC, East Kilbride
Dr Lin Kay	NERC, Swindon
Dr Christoph Schnabel (Secretary)	SUERC, East Kilbride

Applications for CIA support should be made on the appropriate form, copies of which, along with other essential details and submission dates, can be obtained from the CIAF website (www.gla.ac.uk/suerc/nerc/cosmogenic/application.html) or from the Committee Secretary, Dr Christoph Schnabel. Eligibility for CIAF support is restricted to established members of staff in British higher education institutions, or in government-funded institutions (e.g., NERC Research and Collaborative Centre, such as BGS, BAS; National Museums) plus holders of some peer-reviewed personal fellowships, who are eligible to hold NERC grants. The position of the staff member should be clearly stated on the form (Lecturer, Reader, Curator, etc). Research student projects may be supported by CIAF, but these applications must be made by their NERC-eligible supervisors.

There are two deadlines each year and applicants should ensure that completed forms are in the hands of the Committee Secretary by the closing dates that are listed on the website. Late applications will not normally be considered by the Committee which meets approximately four weeks after the closing dates. Where support is required for a PhD student, this must be clearly stated on the form.

The lead-time for analyses will vary, but applicants should anticipate that at least six months (and maybe more) might elapse between submission of samples and reporting of results, although this time may be reduced for samples that have been prepared as targets (see below). Hence, research students and supervisors should plan well ahead when the results are required for the writing up of (normally) a doctoral thesis. In this respect, the Steering Committee welcomes **'in principle'** applications that outline a research project and give an indication of the number of analyses that are likely to be required. In essence, these are 'statements of intent' which will be followed, in due course, by a more detailed submission. The 'in principle' application not only gives the Facility notice of the number of analyses likely to be involved in future requests for analytical support, but also enables the Committee to provide feedback that may strengthen (and therefore increase the chances of success of) the subsequent application. The Committee will also consider **'pilot studies',** applications for analytical support for single samples or small numbers of samples when it is necessary to test the feasibility of a larger project. All potential applicants are encouraged to contact the Committee Secretary if they have doubts about any aspect of the application process. The preferred mode of operation is via collaborative research with CIAF staff, including all stages from application to interpretation and publication of results. One of the NERC criteria for renewal of Facility funding is evidence of scientific contribution of the NERC Facility to approved projects.

A good application should be clear and concise, and individual analyses must be fully justified. It should set out the background to, and context of, the project; should explain in detail why the specific number of analyses requested are needed; and should show how the results will move the science forward. Applicants are reminded that scientific justification must address the wider academic significance of the proposed analyses The application should not exceed six pages of text (12 pt font), including maps, diagrams and references, and there is an overall limit of 2000 words. Details of the applicant's recent publications should be included. It is especially important to explain clearly the site context of each sample, how the sample was taken, and any factors that might affect the analytical results. The last named include, *inter alia*, complex exposure history, aspect, altitude and shielding. It should also be made clear on the application whether the samples will require preparation in the CIAF, or whether they will be submitted as targets. Further information can be found in

Section 3 of the Guidance Notes, which applicants are asked to read carefully before submitting their application.

One further point should be noted. There may be an impression that applications for relatively few analyses stand a greater chance of success. This is not the case. Although the Committee will regard with scepticism applications for large numbers of analyses that are poorly justified, it must be stressed that it is the *quality of the science* rather than the number of analyses requested that determines whether an application is successful. Although the current capacity of the Facility is limited to around 200 analyses per year (based on full preparation of rock samples to target), the Committee has made allocation of upwards of 20 analyses to individual applications where the scientific merit of the project has been deemed to be high. In addition, the Committee has, on occasion, awarded additional analyses where it felt that the quality of the research, as reflected in the application, required them. It is important, therefore, that applicants are not deterred from applying for sufficiently large numbers of analyses to address their project aims; these must be fully justified, however, and placed in the context of the research project. Where projects exceed 20-30 analyses, NERC expects applicants to have secured a NERC grant, or an alternative source of contributory funding.

Finally, the Committee would encourage all those seeking analytical support to contact the Committee Secretary if they have any queries regarding any aspect of the applications procedure. The Committee is anxious to stress that, while its primary role is to ensure that the highest research standards are maintained, both it and the Facility exist to provide a service to the user-community. Interaction between the community and Facility personnel is regarded as an integral component of both the application and the analytical process (see below).

Peer review

As noted above, each application is evaluated purely on the basis of research quality. After review, applications are graded using the alpha numeric system employed throughout NERC: $\alpha5$ international level science/research; $\alpha4$ – international/national science/research; $\alpha3$ – nationally important science/research; $\alpha2$ - science/research of national/regional interest; $\alpha1$ - science/research of regional/local interest; β – science/research of adequate quality; R- reject. Current funding levels allow only those projects graded at $\alpha4$ and above to qualify for analytical support, although PhD student projects graded at $\alpha3$ *may* be funded. NERC and the Committee are strongly committed to assisting PhD students and will often offer advice on improving applications made on their behalf. Furthermore, it is strongly recommended that postgraduate (PhD) students visit the Facility to assist with the analytical work and discuss their project as part of their research training.

The Committee does not encourage proposals that are allocated a grade below the $\alpha 4$ threshold to be recast and resubmitted. However, in certain circumstances the Committee may *invite* a resubmission (grade R*). An R* grading means that, while the Committee feels that the overall project has merit, they regard the proposal in its current form as deficient and hence it cannot be supported as it stands. Deficiencies may take a number of forms: the application may lack context or focus; the sampling strategy may not have been fully and clearly explained; the justification for the number of analyses might be inadequate; or the wider significance of the results may not appear to have been appreciated. In the case of an R*, the application is referred back to the submitter with a full explanation of the shortcomings, and a resubmission is invited. In certain circumstances, for example where a student is involved and the thesis deadline is imminent, the resubmitted application may be dealt with under urgency procedures.

Some feedback is normally provided in regard to both successful and failed applications as was emphasised above, the Committee encourages interaction between itself and the user-community, and applicants are invited to contact not only the Committee Secretary, but also the Committee Chairman, particularly if they have queries related to resubmitted applications. NERC has an established complaints procedure, should other avenues not provide satisfaction.

Analytical support and sample submission

Once CIAF support has been approved by the Committee, successful applicants will be notified (normally within two weeks), and they will be invited to submit their samples to the Facility. Sample submission may take two forms: (a) whole rock samples may be sent to the Facility for crushing, mineral separation (where appropriate) and target preparation; (b) alternatively, where applicants have access to preparation facilities, perhaps in their own institutions, the samples may be despatched in the form of either crushed samples or fully-prepared targets. In the case (b), it is *essential* that the applicants liaise closely with the Facility to ensure that the appropriate quality assurance protocols are followed for all stages of target preparation. Samples should be accompanied by the completed sample submission form (electronic submissions are preferred, using the form available on the website). Turn-around times will vary depending, for example, on the degree of preparation required, on the nature of the sample material (e.g. quartz, feldspar) and/or the nature of the analyses required (^{10}Be, ^{26}Al, ^{36}Cl), and on the backlog in the laboratory at the time of submission. Every effort is made by the CIAF to meet any deadlines indicated on the applications forms where these might relate, for instance, to the writing up of a doctoral thesis or to the submission of a research grant report. Again, the Committee is anxious to encourage contact between submitters and CIAF staff, and who will be able to give an indication of the lead-time for the results and to keep submitters informed on progress.

Notification of the analytical results will be made to the Principal Investigator listed on the original application form, and it is assumed that they will communicate this information to any collaborators. The notification letter will be accompanied by a full description of the results, and a form on which comment is invited on the outcome of the analytical exercise. It is important that applicants respond by adding observations where appropriate before returning the forms to the Committee Secretary. Ownership of the analytical results remains with the submitter and NERC for two years after the analytical results are issued. Results will not be published within two years by NERC without the approval and co-operation of the submitters: this allows maximum exploitation of data for publication by researchers. After this time, however, NERC may exercise its joint ownership of the results by releasing these into the wider community. The support of NERC and the CIAF must be acknowledged in any publication in which the results are used. Copies of these publications, or references to the publications, should be sent to the Facility. Publications are an essential measure of the performance of the Facility, and PIs are sent periodic reminders for an up-to-date list of CIAF-supported publications for inclusion in the Annual Report of the Facility.

Finally, although customer satisfaction questionnaires are sent periodically to applicants, the CIAF Committee Chairman welcomes constructive comments on possible improvements to the analytical service from users and potential users alike.

Note

This paper is a follow-up to two previous publications describing the Radiocarbon Dating Service provided by NERC. These are: Walker, M.J.C. & Edwards, K.J. (1999): Radiocarbon dating in Britain: the role of the Natural Environment Research Council Radiocarbon Steering Committee. *Quaternary Newsletter*, **87.** 28-35, and Caseldine, C., Saville, A., Kay, L. & Millward, C (2004): Radiocarbon dating in Britain: the role of the Natural Environment Research Council Radiocarbon Steering Committees – additional guidance for applicants. *Quaternary Newsletter*, **104**, 12-19.

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REPORTS

THE GROWTH, MAXIMUM EXTENT AND DEGLACIATION OF THE LAST BRITISH AND IRISH ICE SHEET

QRA ANNUAL DISCUSSION MEETING – 4- 6TH OF JANUARY 2007, ST ANDREWS

The QRA Annual Discussion Meeting 2007 was hosted by the University of St. Andrews under the title "The Growth, Maximum Extent and Deglaciation of the last British and Irish Ice Sheet". This theme brought together Quaternary researchers from the terrestrial, marine and modelling communities.

The meeting was jointly organised by Dr Bill Austin, Prof. Colin Ballantyne, Prof. Doug Benn (University of St Andrews and UNIS), Dr David Evans (Durham University), Prof. Danny McCarroll (University of Wales, Swansea) and Prof. James Scourse (University of Wales, Bangor). The meeting consisted of two full days of presentations, oral and poster, a well attended conference dinner with guest of honour **Dr Brian Sissons**, as well as a fieldtrip exploring sites of interest from the coast of Fife to the Drumochter Pass. The John Wiley Lecture 2007 was given by **Prof Hans Petter Sejrup** (University of Bergen, Norway) on the Pleistocene glaciations of the North Sea. Over 120 delegates attended the conference.

The meeting brought together Quaternary practitioners from across the broad spectrum of the discipline. Presentations from the terrestrial, marine and modelling fields gave a flavour of the current state of knowledge with regard to the last British and Irish Ice Sheet (BIIS). In addition, common concerns and questions central to the furtherance of research in this area were expressed, *inter alia*, the importance of data regarding the build up of ice, the role of ice streams and multiple ice centres, rates of advance and decay and the significance of the ice raft debris (IRD) signal in marine records.

The terrestrial presentations were principally divided into the contribution of Irish, Scottish and Welsh Ice (as well as the extent of ice in the Isle of Man, Yorkshire and Lancashire), the mapping of glacial features and the dating of these landforms. The marine presentations dealt with the ocean basins surrounding the British Isles, the North Sea and Celtic Sea in particular and the contribution of IRD, as a continuous record of deposition in the reconstruction of ice sheet dynamics. Modelling presentations focused on the importance of ice streams and multiple centres for the last British and Irish Ice Sheets.

Irish Ice Sheet dynamics were discussed; in particular the re-evaluation of existing models of ice extent, the possible presence of several ice domes, the detailed and systematic mapping of the glacial landforms and the chronological controls of those landforms. **Prof. Colin Ballantyne** (University of St Andrews) lead the re-evaluation of current conceptual models by establishing the maximum ice altitudes for the mountains fringing the Central Plain of Ireland using geomorphological evidence (trim lines) validated by soil clay-fraction mineralogy and ^{10}Be exposure dating. The results suggest a thick ice cover for the Irish mountains at the Last Glacial Maximum (LGM) except at the highest summits, which remained as nunataks above the ice surface or supported a thin cover of cold based ice. This is contrary to traditional models and supports the idea of an offshore extent of the British and Irish Ices Sheet at the LGM. **Dr Cathy Delaney** (Manchester Metropolitan University) also intimated a more complex pattern of ice sheet formation and dynamics through research of subglacial lineations, esker formation and the presence of a large proglacial lake in the Midlands basin. The proglacial lake and the extensive conduit system caused the "unzipping" of a single western ice dome, via downdraw of ice and reorganisation into two domes. A more complex picture of Irish Ice Sheet dynamics was also described in work by **Drs Colm Ó Cofaigh** and **David Evans** (presenting) (Durham University). Evidence from the dating of glacially transported marine shells within the "Irish Sea Till" suggests that most of southern Ireland was glaciated at the LGM. In addition they propose that the rapid advance of the ice sheet to its maximum extent in the Celtic Sea was facilitated by bed conditions rather than by climate factors alone and it was a relatively short lived feature, as indicated by the absence of thick deglacial depocentres. This is in contrast to sites further north in the Irish Sea Basin associated with the stabilisation of the ice sheet in the narrow corridor between Wales and SE Ireland.

A potential reconsideration of the dynamics of Scottish ice during the last glaciation and its extent was proposed by presentations from those working on the terrestrial record for Scotland. **Dr Adrian Hall** (Fettes Collage, Edinburgh) indicated that existing models may require revision in light of ^{10}Be dating of erratic boulders and glacially eroded bedrock in so-called ice free enclaves (Caithness, western Buchan and western Mainland, Orkney). A reconstruction of the last ice sheet in The Moray Firth indicates a complex interaction with other ice masses over the Northern Highlands, Shetland and the North Sea. **Mr Nicholas Golledge** (British Geological Society, Edinburgh) presented a new model of the Younger Dryas ice cap system for an area of the western Highlands developed from new geological and geomorphological data. The data provides additional insight into the complex and dynamic evolution of the Younger Dryas ice cap in western Scotland where equilibrium, if reached, may have been short lived and the ice cap may have suffered a mass imbalance throughout its existence. Also for the Younger Dryas of Scotland, **Dr Adrian Palmer** (Royal Holloway, University of London) presented initial research on the internal structure of laminated deposits formed in glaciolacustrine systems in Glen Speen and Glen Roy during the Loch Lommond Stadial. Summer layer data was compared to the $\delta^{18}O$ variations in the GRIP ice core record and this suggested the Younger Dryas ice cap on mainland Scotland reached its maximum extent ca. 840 years after the equivalent event in the Greenland ice record. In addition, both Greenland ice and Scottish glaciolacustrine sedimentation appear to respond to a common forcing factor. In a presentation of analysis of a glaciotectonised organic deposit at Balglass Burn, a location close to the centre of ice accumulation in Scotland, **Dr Eleanor Brown** (The Countryside Agency and Royal Holloway, University of London) and **Prof Jim Rose** (presenting) (Royal Holloway, University of London), indicate the presence of at least discontinuous permafrost from *Coleoptera* temperature reconstruction during Marine Isotope Stage (MIS) 3. This calls into doubt the assertion that the British Ice reached its maximum extent before 37 ka BP. These presentations appear to reinforce the findings of those working on the Irish Ice Sheet and marine margins of the North West British Ice Sheet, as to the dynamic and highly complex nature of the last BIIS.

The complex nature of the last British and Irish Ice Sheets was further illustrated by the presentation of **Dr David Roberts** (Durham University) on the glacial history for the Isle of Man which suggested that this portion of the Irish Sea Basin had many of the characteristics of an ice stream: flow convergence up-ice, a grounding line in the Celtic Sea and recessional limits indicative of a rapidly oscillating ice margin. Similarly, the complexities of glacial history of the Rossendale Forest and Greater Manchester are only beginning to be understood. Remapping, including the examination of over 30,000 boreholes and trial pits presented by **Mr Richard Crofts** (British Geological Survey, Nottingham) has established a preliminary chronology of the ice sheet across Lancashire and the Cheshire-Shropshire plain. **Dr Mark Bateman** (University of Sheffield), using luminescence dating of glaciofluvial and glaciolacustrine deposits from Yorkshire, demonstrated that ice extended into the south of the Vale of York and that ice was capable of blocking the Humber gap creating the extensive pro-glacial Lake Humber.

The importance of detailed and comprehensive mapping of glacial landforms to the interpretation of the history of the last BIIS was highlighted in several presentations. Stunning examples of the detailed mapping work for Ireland and Britain, developed from the BRITICE project, were given by **Ms Anna Hughes, Ms Sarah Greenwood** and Dr David Evans on behalf of **Prof. Chris Clark** (University of Sheffield). Similar detailed geomorphological mapping of the Welsh Mountains was presented by **Miss Eva Sahlin** (University of Wales, Aberystwyth).

The significance of dating for Quaternary research was reinforced in much of the discussion. **Dr Richard Gyllencreutz** (University of Bergen) brought to the attention of the meeting a new database which aims, in time, to bring together all available dates of the Eurasian ice sheet growth towards the LGM as well as deglaciation. The first version of DATED will be published and made available online in August 2007. **Dr Derek Fabel** (University of Glasgow) presented initial results from West Antarctica and Sweden that may inform the interpretation of complex exposure histories of cosmogenic radionuclide dating through the use of marine or ice core isotope records as a proxy for the timing and duration of ice cover. **Dr Geoffrey Thomas** (University of Liverpool) presented details of architectural element analysis and sequence stratigraphy in the identification of repeated retreat-stage ice-marginal oscillations in pro-glacial sediment basin fills. This technique, from which evidence for ice-marginal readvance during deglaciation was presented, allows the simplification and clarification of stratigraphic sequences through horizontal compression.

The *marine* presentations from ocean basins surrounding the British Isles, the North Sea and Celtic Sea in particular, presented biostratigraphical, lithological especially IRD records, magnetic and 3D reflection seismic data. **Professor Hans Petter Sejrup** (University of Bergen) gave the 2007 John Wiley Lecture on the Pleistocene glaciations of the North Sea. The possibility of the coalescence of the European ice sheet with the BIIS in the North Sea and the presence of a large ice dammed lake were discussed using data from two sites; the strongly ice stream influenced Norwegian channel and from the continental slope north of the eastern North Sea. In addition, **Dr Lidia Lonergan** (Imperial College, London) presented evidence for buried submarine landforms mapped using 3D reflection seismic data. These buried landforms indicate the presence and subsequent break up of fast flowing grounded ice sheets thus lending independent support to reconstructions of complete ice coverage between Scotland and Norway during the LGM. Large scale ice sheet bedforms identified in NW Scotland and The Minch were presented by **Dr Tom Bradwell** (British Geological Survey, Edinburgh). These mega-scale lineations represent the coherent geomorphological signature of a large palaeo-ice stream. The spatial distribution and pattern of streamlined bedforms around The Minch has enabled the catchment, flow path and basal shear stresses to be tentatively reconstructed. The ice sheet configuration may have been caused by ice piracy as The Minch ice stream grew, possibly influencing ice sheet thickness across the whole region.

Professor James Scourse (University of Wales, Bangor) presented data for the growth, dynamics, maximum extent and deglaciation of the Celtic Sea from a transect of both onshore and offshore sites extending from the Isles of Sicily. A landbridge is proposed in the northern Celtic Sea. IRD records presented support recent evidence of an inundated lake in the Celtic Deep during the late glacial. The intricacy of interpreting IRD records was highlighted. This was reinforced by other marine presentations.

Dr Bill Austin (University of St Andrews) concentrated on the marine record through MIS 3 for a site on the Hebridean margin of NW Scotland. In particular, IRD events were framed within the context of Dansgaard-Oeschger (D-O) cycles and the dynamics of the BIS behaviour framed in the context of ice sheet expansion through MIS 3. In addition, convincing evidence for the grounding of the BIS on the Hebridean Shelf at the time of Heinrich Event 4 (ca. 38cal ka BP) was presented. This created an interesting point of contrast with ice-free onshore evidence at around this time. **Dr Stephen Davison** (BGS, Edinburgh – currently University of Edinburgh), using geophysical and borehole data, investigated ice streams and ice sheet limits from the west Shetland margin. These suggest ice sheet expansion in the west Shetland area advanced from both the Scottish mainland and north-westwards from Shetland, with possibly two phases of glaciation reaching the outer shelf. An oscillating retreat from the shelf edge is proposed from moraine distribution. Marine palynology, dinoflagellate cysts (dinocysts), was used by **Mrs Angela Morris** (University of Glamorgan) (presented by **Dr Tony Harris**) in conjunction with the flux in BIS IRD during the last deglaciation, to relate changes in ice sheet growth to changes in surface ocean temperatures. An oceanic link was confirmed by the changes in dinocyst assemblages on timescales similar to the D-O oscillation of Greenland ice.

Dr John Walden (University of St Andrews) demonstrated the compositional variability of IRD from cores along the NW European continental slope. Changes in composition were explained as variation in contribution of IRD sources to these sites. Magnetic signatures could be discerned for IRD derived from the Laurentide ice sheet and ice streams from the southern (Irish Sea) or northern (NW Highlands) BIS. Semi-quantitative estimates on the changes in supply from these source regions were obtained by source unmixing models thus providing a record for BIS IRD activity through the last period of growth and decay. The potential of the method as a means of extending records of ice sheet activity beyond those currently available from terrestrial records was suggested.

The potential for ice streams and multiple ice centres, as well as the highly complex evolution and dynamics of the last BIIS, was demonstrated in many *modelling* presentations. The low profile, low summit elevation with extensive lobes documented by terrestrial records appears to be confirmed. **Professor Geoffrey Boulton** (University of Edinburgh) highlighted the importance of ice stream dynamics and demonstrated, by a thermo-mechanically coupled numerical ice sheet model, that ice sheets may be very sensitive to mass balance and "continentiality". Marginal lobes were found to reflect streaming. Such streams may be ephemeral and dynamic with locations determined by ice sheet properties or fixed, determined by bed properties. Initial results presented by

Dr Alun Hubbard (University of Edinburgh, currently BGS Edinburgh) reveal a dynamic, relatively low aspect ice sheet with much of the base grounded below sea level. In addition, the ice sheet contains numerous independent accumulation centres with a series of fast flowing outlet glaciers and ice streams mobilised by rapid basal motion. A request for increased field constraints on interior ice elevation and thermal regime was put to the meeting. The model presented by **Dr Andreas Vieli** (Durham University) reproduced, in more general terms, the highly complex preceding models in that a very dynamic ice sheet was seen with no real steady state being reached. The paucity of field data, terrestrial or marine, relating to ice sheet build up towards the LGM, was again highlighted. Relative sea level changes, glacial isostatic modelling and ice sheet reconstructions since the LGM was presented by **Professor Ian Shennan** (Durham University). A good fit was demonstrated for relative sea level observations and predictions, based upon far field data and the ice sheet model. The model, which was adjusted for terrain elevation beneath the ice surface, includes extensive glaciation of the North Sea and western continental shelf; trimline data constrains ice surface elevation and the model does not assume isostatic equilibrium at the LGM.

FIELDTRIP – St Andrews and the Fife Coast to Drumochter Pass

Over forty delegates braved the January elements for a fieldtrip enthusiastically led by Professors Colin Ballantyne, Alastair Dawson and Doug Benn (University of St Andrews, Aberdeen and UNIS) and highlighted:

a) Interglacial, Lateglacial and postglacial shorelines and ice retreat from east Fife – an introduction and overview of ice retreat and shoreline development was given at the first stop at Strathkinness, followed by stops illustrating the postglacial shoreline and Holocene dunes of Tentsmuir Forest and the Lateglacial delta/ kame terrace of North Straiton gravel pit.

b) Sea level change in the Tay Valley was discussed at a stop at Newburgh, in particular, the dating and significance of the Errol Clays.

c) Ice retreat across the Highland boundary from outwash landsystems was examined at Killiecrankie and Glen Garry outwash terraces.

d) The Loch Lomond Readvance was considered at stops within Glen Garry looking at recessional moraines, meltwater channels, Loch Garry deltas and shorelines, as well as stops at Drumochter Pass, Balsporran and North Drumochter before returning to St Andrews.

The meeting illustrated the diverse nature of Quaternary research, as well as cross discipline co-operation, in unravelling the complex chronicle of the growth, maximum extent and deglaciation of the last British and Irish Ice

Sheets. A very good level of discussion was stimulated by the theme chosen. This was a well balanced meeting that brought together communities for discussion of a very timely research topic. Collaboration between onshore and offshore groups, linked by a dynamic modelling approach is likely to prove very promising in the unravelling of the history of the last British and Irish Ice sheets in the next few years. The organising committee are to be commended for a stimulating choice of theme and the excellent organisation of both the meeting and the fieldtrip.

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THE QUATERNARY OF THE BRECON BEACONS

QRA ANNUAL FIELD MEETING, BRECON, 22ND – 26TH APRIL 2007

Sunday, 22nd April

Following a delicious 3-course dinner, around 50 participants were given a number of introductory talks that set the scene for this year's QRA Annual Field Meeting. **Simon Carr** (Queen Mary, London) opened with a general overview of the area surrounding the Brecon Beacons and its glacial history. **Adrian Humpage** (BGS) provided an overview of the bedrock geology and an introduction to the Fforest Fawr Geopark which includes most of the area visited on this meeting. Finally, **Rick Shakesby** (Swansea) focused on the patterns, size and significance of Younger Dryas glaciation of the Brecon Beacons to establish a basis for the discussions that were to follow over the next few days. **Simon Carr** concluded this introduction to the AFM with some organisational information and crucial advice (Don't forget your waterproofs!).

Monday, 23rd April

Llyn y Fan Fach

After having climbed up a track through the mist and drizzle in less than 50 m visibility, **Rick Shakesby** and **Simon Carr** described the surroundings of Mynydd Du (the Black Mountain) to the south of Llyn y Fan Fach, of which little could be seen through the clouds and horizontal rain. However, a wave of cheer and laughter passed through the group as a series of colour prints, taken on a sunny day, were passed around. **Rick** then described the geomorphological evidence for local glaciation and periglaciation in this area, elaborating on the traditional geomorphological approach he had laid out the night before. Seven discrete ridges, for which multiple interpretations can be put forward, have been described from scarp-foot settings in this area. Depending on their distance from the scarp-foot, their size, planform and shape of surficial clasts, these have been either interpreted as pronival ramparts, ice-marginal moraines, rock-slope failures (RSF) or rock glaciers. Despite their disputed origin, radiocarbon dating at some locations appears to suggest a Younger Dryas age for many of these landforms. **Simon Carr** then outlined how a glaciological approach could be used to test these different interpretations and to discriminate landforms of glacial from those of periglacial or paraglacial origin. Numerical models that simulate the amount of sun shading, calculations of the contribution of snowblow from surrounding plateaux into corries and lateglacial summer temperature estimates were utilised to assess the glaciological feasibility of potential glaciers to form the ridge in question. This approach identifies certain glaciological boundary conditions that should be satisfied if a ridge was to be confidently interpreted as a moraine. Conversely, if these requirements were not met, alternative models of ridge formation could be proposed. A discussion on the age and significance of these landforms ensued, highlighting the importance of the correct (palaeoclimatic) interpretation of these features. If most of these ridges indeed represented moraines, it was argued, the Brecon Beacons would have been the southernmost area that had been glaciated during the Younger Dryas. Research by **Alistair Curry** (OMF International, Cambodia) on the paraglacial response of oversteepened slopes to deglaciation and its significance for the production of talus near the scarp-foot of numerous slopes in the area was summarised by **Simon Carr.** After this, the group split into two parties to pursue either a lowland or upland option.

Upland option

Despite the deteriorating weather about half the group choose the upland option. The ridge-sites visited were as interesting as their names unpronounceable (e.g. Pwll yr Henllyn, Cwm Sychlwch, Gwan y Cadno and Llyn y Fan Fawr), and several enthusiastic discussions led by **Simon Carr, Rick Shakesby** and **Chris Coleman** (Oxford Brookes) took place. The striking characteristic of all the individual, isolated ridges in relation to the escarpment is that the majority have a northerly aspect, are comparatively short (tens to a few hundred metres long) and only a short distance (100-300 m) downslope of the escarpment. While the interpretation had so far been limited to geomorphology, numerical simulations of shading effects show that most of these locations are significantly sheltered from solar radiation and could in principle represent moraines deposited by corrie glaciers. **Dave Evans** (Durham) suggested that cold-based plateau-ice might have fed these glaciers in some places. Another point of discussion concerned the most appropriate modern analogue for these sites, for example whether these landforms were formed in an environment similar to present-day Svalbard or Norway. **John Lowe** (Royal Holloway, London) suggested that the landforms were most likely formed time-transgressively during the lateglacial and might thus not carry the same palaeoclimatic signature. **Sven Lukas** (Bern, Switzerland) noted the absence of basic and more detailed sedimentological studies and the difficulties arising from relying too heavily on geomorphological reasoning and numerical modelling. However, the fact that most landforms are part of a National Park complicates the creation of exposures; geophysical techniques might be an alternative, non-destructive solution in such areas. The majority of participants agreed that more independent temperature estimates near these sites, sedimentological work and incorporation of these results in numerical models are needed to solve the questions of ridge genesis.

A welcome interlude was provided by **Gwilym Hughes** (CAMBRIA Archaeology) who presented the findings of an excavation of a Bronze Age round barrow on the summit of Fan Foel (781 m). This burial mound was found to be surrounded by a stone kerb and contained, in two stone cists, the cremated remains of an adult and two children. Again, discussions ensued on the significance of this site and what the social status of the cremated might have been. It transpired on the walk to the last two ridge-sites of the day that several people's boots had been transformed into water-filled buckets during the stop at the burial mound. This discomfort, combined with the wind and horizontal rain, began to show its effects, but this did not stop speculation at the last two ridge-sites as to whether one might represent a composite feature while the other might represent a bedrock feature or even an impact crater.

Lowland option

After careful evaluation of the increasingly Heathcliffe-esque conditions, the rest of the group decided that a trip to the lowlands, and an opportunity to actually see the sites under discussion, was sensible. To the accompanying smell of burnt clutch (courtesy of QMUL van), the party set off to the first site at **Llywn Meurig**, where **Adrian Humpage** provided an overview of LGM glaciation within the Usk Valley and possible source areas of the ice. A lengthy exposure of diamict behind the local farm buildings afforded an opportunity to search for clasts that could test competing hypotheses regarding the ice source. The consensus amongst participants was for a more local origin, with the notion of mid-Wales ice being received sceptically.

Next stop was **Cefn Crai** where **Adrian Parker** (Oxford Brookes) and **Pete Coxon** (Trinity College Dublin), enthusiastically supported by the farm dog, treated us to a masterclass in coring, a grand QRA field meeting tradition. The site is interpreted as a Kettle Hole, contains a typical lateglacial tri-partite sequence, recording the Windermere Interstadial, the Younger Dryas and the early Holocene, represented by minerogenic sediments of Younger Dryas age sandwiched between two organic units. Cefn Crai offers an opportunity to provide a constraint on the deglaciation of LGM ice in the Usk Valley, although only Holocene material was recovered on this coring attempt. Despite this setback, the dog seemed pleased enough.

The convoy then drove along the Nant Gwydderig valley, turning off the A40 near the village of **Llywel**. Here, the group observed some highly impressive, low-angle, alluvial fans of Holocene age as well as a large exposure behind a local dwelling, with **Adrian Humpage** again leading the discussion. Adrian argued that the section represents two phases of deposition; an ice-marginal, glaciofluvial ice contact deposit overlain by a steep sided fan gravel deposit.

Post tea shop break, the final stop of the day represented a departure from the dissection of glacial history and a trip back into the much more recent past at **Rhandirmwyn**, the slightly apocalyptic looking site of a former lead mine. Here, **Tim Mighall** (Aberdeen) provided a fascinating introduction to the history of lead mining at this location and further afield. Mighall and colleagues use geochemical data from peat bog archives located close to mining sites to infer past industrial activity. At Rhandirmwyn, significant mining took place in the 18th century, with indications of two less dramatic episodes having occurred prior to this, one possibly as early as the Iron Age (though Tim stressed the need for caution in this interpretation).

Tuesday 24th April

Craig y Fro

The group, reunited and in much drier weather, visited three key localities on the second day. Starting at Craig y Fro, where a complex of ridges occurs downslope of a steep scarp, **Rick Shakesby** made the case for a glacial origin of these features. In particular, he referred to a core taken by **Mike Walker** (Lampeter) and analysed for pollen in a basin between the ridge complex and the scarp that showed a typical early Holocene flora and a basal radiocarbon age that corresponds well with the end of the Younger Dryas. **Simon Carr, Chris Coleman** and **Dave Evans** then presented their alternative interpretation of the features as a RSF, supported by evidence from geomorphological mapping, glacier reconstruction and numerical modelling of radiation shading. **Wishart Mitchell** (Durham) highlighted that such complex terrain can easily be produced by RSFs and that our understanding of such features is complicated by the scarcity of detailed studies. Furthermore, re-coring of the basin revealed that Mike had only recovered the top part of the succession, with a longer time-period being preserved in the basin. Individual discussions by members of the group during a walk-over reconnaissance appeared to generally favour a RSF interpretation, although sadly no formal vote was taken.

Craig Cerrig-gleisiad

This cirque below an L-shaped escarpment contains several ridges that have been interpreted as moraines. **Rick Shakesby** outlined the history of research and also drew attention to the features glacial processes could not account for, e.g. the presence of rotated bedrock blocks and tension cracks near the foot of the scarp. After a short walkover of the cirque floor Rick and **Simon Carr** jointly led discussions as to whether the ridges might more likely be the result of a glacially-modified rockslide in the upper parts of the cirque, an explanation that most people seemed to accept. **Ian Evans** (Durham) placed the significance of this site into a wider context by explaining how cirques might be formed by a combination of repeated cycles of mass movements and subsequent glacial erosion.

Traeth Mawr

This site is one of key sites recording palaeoenvironmental change throughout the lateglacial in the Brecon Beacons. **Adrian Humpage** explained the geomorphological context, which represents a large kettle hole dammed by a till plain to the north and a moraine marking a stillstand phase of ice retreat into the Brecon Beacons to the south. **John Lowe** then took over to explain the litho- and pollen stratigraphy of a core obtained by **Mike Walker**. The coring demonstration was performed by none other than **John Lowe** and **Pete Coxon**, at times supported by **Adrian Palmer** (Royal Holloway, London), who took only seven attempts to recover the basal sediments they were looking for at a depth of 4.95 m. This sequence turned out to be classical tripartite. A discussion on the use of biological proxies to reconstruct palaeoclimatic conditions and the pitfalls associated with their interpretation rounded off the day's itinerary.

Wednesday, 25th April

This day was devoted to the bigger picture of glacial events in the Usk Valley to the south and south-east of the Brecons. **Geoff Thomas** (Liverpool) introduced the itinerary of the day and explained how the Late Devensian ice masses sourced in the Brecons and Black Mountains to the north and northwest reached their maximum in the Usk Valley. At present there appears to be a number of contrasting interpretations as to the glacial extent and flow patterns depending on the methods used (remote sensing versus fieldwork).

Following a brief stop at The Bryn where Holocene river terraces were presented and discussed by **Geoff Thomas** and **Adrian Humpage**, several ice-marginal features around the area of Abergavenny were visited by the group. **Adrian Humpage**, **Chris Coleman** and **Geoff Thomas** interpreted them, based on morphological grounds and limited exposures, as moraines, kames and associated sandur deposits relating to the maximum extent of the Late Devensian ice sheet and its decay.

Following a much-earned lunch-break, the group visited the site of **Llangorse Lake** where **Adrian Humpage** introduced the geomorphology of the site. The present lake is the remnant of the much larger glacial lake Llangorse which was dammed up by ice retreating down the Llynfi valley during Late Devensian deglaciation. Moraines that can be traced across the lower parts of the valley record four stages where the ice halted and/or readvanced during retreat. **Adrian Palmer** introduced the group to the pre-Holocene sedimentary stratigraphy of cores taken in a similar location to those by **Mike Walker**. Detailed logging and micromorphological analyses of this core revealed a fourfold stratigraphy. A diamicton at the bottom, interpreted as a Late Devensian till relating to ice advance up the valley, is overlain by alternating clay and sand layers that appear to represent the initial stages of the establishment of glacial Lake Llangorse. This is followed by a succession of silt and clay laminations that are likely to represent glacial varves that are annually resolved and record seasonal differences in sediment input to this glaciolacustrine system. The top of the succession is formed by marl deposits that **Mike Walker** and others interpret as representing lacustrine conditions, based on palynological, ostracod and mollusc analyses as well as radiocarbon dating. Compared to this rather neat overall stratigraphy, **Frank Chambers** (Gloucestershire) described how the Holocene stratigraphy of the lake was rather complicated, largely through the lack of age control on the formation of individual units. Discussions on the various models of lake formation, their links to glacial termini and the potential meaning of missing deltas rounded this site off.

The final stop of the day, **Waen Ddu**, a raised bog beneath the escarpment of Mynydd Llangattwg, was presented by **Chris Coleman**. The geomorphology of this site appeared to be rather complex with ridges, partly composed of "erratic" bedrock fragments, providing the downvalley rim for the raised bog in the basin below the escarpment. This site is currently convincingly interpreted as a rotational rock slide which was then glacially modified explaining moraine ridges and seemingly "erratic" bedrock outcrops in the basin below the escarpment.

Thursday, 26th April

After hearty farewells early in the morning, the remaining 26 participants were led by **Simon Carr** to explore the style of Younger Dryas glaciation in the Brecon Beacons proper, in sunny and mild weather conditions for a change. The first stop, Waun Rydd Plateau, was used to illustrate the location of a series of benches that trend across the cirque floors and were too far away from cirque headwalls to be convincing examples of pronival ramparts. **Dave Evans** brought up the issue of a distinct possibility of there having been a connection to plateau ice in some of the presented cases, and discussions ensued on the problems associated with identifying the presence and extent of former plateau ice and its implications for reconstructions of equilibrium-line altitudes. The group was also shown a textbook example of a rock slope failure that had not been subsequently modified by glacial activity (Cwar y Gigfran), and **Chris Coleman, Rick Shakesby** and **Simon Carr** then led the group to the cirques Cwm Oergwm and Cwm Pwllfa where again the possible modes of formation of various cross-cirque floor ridges were enthusiastically discussed in detail. Cwm Pwllfa was a very good choice for the last stop of the day as it contained spectacular ridges that were > 10 m high, continuous and came closest to what most of the participants had regarded as moraines prior to this trip. In addition, **Simon Carr** and **Chris Coleman** presented data from cores taken in collaboration with **Adrian Parker** within the basin dammed up by the moraines. The basal organic sediments could be dated to the early Holocene (8290±35a BP), which indicates that the moraines are very likely to have formed during the Younger Dryas. However, there is still uncertainty about the 2000 years following the termination of the Younger Dryas as dated elsewhere in Europe and the onset of organic sedimentation. The participants agreed that much further work was needed in Cwm Pwllfa, but also elsewhere in the Brecon Beacons, to resolve the extent, chronology and palaeoclimatic significance of lateglacial glaciations in this area.

Concluding remarks

Overall, the field meeting was a highly enjoyable, informative few days that revealed interesting new ideas and stimulated some keen discussions. What is clear from this meeting is that there is plenty of scope for further research in this spectacular area. In this respect, the accompanying field guide will serve as an excellent starting point for anyone wishing to explore this area for themselves. Particular thanks go to **Simon Carr** and his team for the flawless organisation of the whole meeting, in particular the balanced selection of field sites, keeping to schedule and, last but not least, the excellent choice of venue.

References

Carr, S.J., Coleman, C.G., Humpage, A.J., Shakesby, R.A. (2007). *The Quaternary of the Brecon Beacons: Field Guide*. London: Quaternary Research Association, 277 pp.

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QUATERNARY RESEARCH FUND

THE INSECT REMAINS FROM LATE HOLOCENE PEATS BENEATH THE RIVER CLETTWR, CEREDIGION, MID WALES

Introduction

The inter-tidal peats of Borth and Ynyslas have received considerable palaeoecological analysis and research over a period of almost seventy years beginning with the work of Godwin (1938) through to the more recent work of Hughes and Schulz (2001). Recently, channel migration of the Afon Clettwr (Figure 1), which flows into the Dyfi Estuary approximately four kilometres from the mouth of the Dyfi at Ynyslas, has revealed the remains of a submerged forest within the Estuary itself (Figure 1). Associated with this forest is a peat bed approximately 1.2m deep, documented by Shi and Lamb (1991). Radiocarbon dates indicate peat formation commenced *c*. 5280±60 ^{14}C years BP (6180-5900 cal BP, Beta-206437) and ceased *c*. 4540±50 ^{14}C years BP (5310-4970 cal BP, Beta-206436).

None of the peats at Borth, Ynyslas or within the Dyfi Estuary itself have previously been subject to palaeoentomological analysis. An opportunity for such analysis arose in March 2005, when low spring tides permitted sampling of the Afon Clettwr peat bed for pollen, insect and waterlogged plant remains. The basal deposit was predominantly composed of estuarine silts and clays with some organics and fragments of reed (*Phragmites* spp.), the peat is composed of a lower band of sedge peat with some wood giving way to what appears to be a homogeneous sedge peat. Five bulk samples (10l) were recovered from the section and processed using the standard method of paraffin flotation as outlined in Kenward *et al*. (1980). The insect remains were then sorted from the paraffin flot and identified under a binocular microscope. Where possible, the insect remains were identified by comparison to specimens in the Gorham and Girling collections and with other archaeological specimens.

Results

A large, diverse and well-preserved assemblage was recovered from all five samples, the environments indicated by the coleoptera vary little throughout the profile: Vegetation dominated by *Carex* spp. with patches of *Calluna* spp. or *Erica* spp., interspersed by fresh water pools or streams with tall, emergent riparian vegetation; aquatic conditions fluctuate throughout the profile.

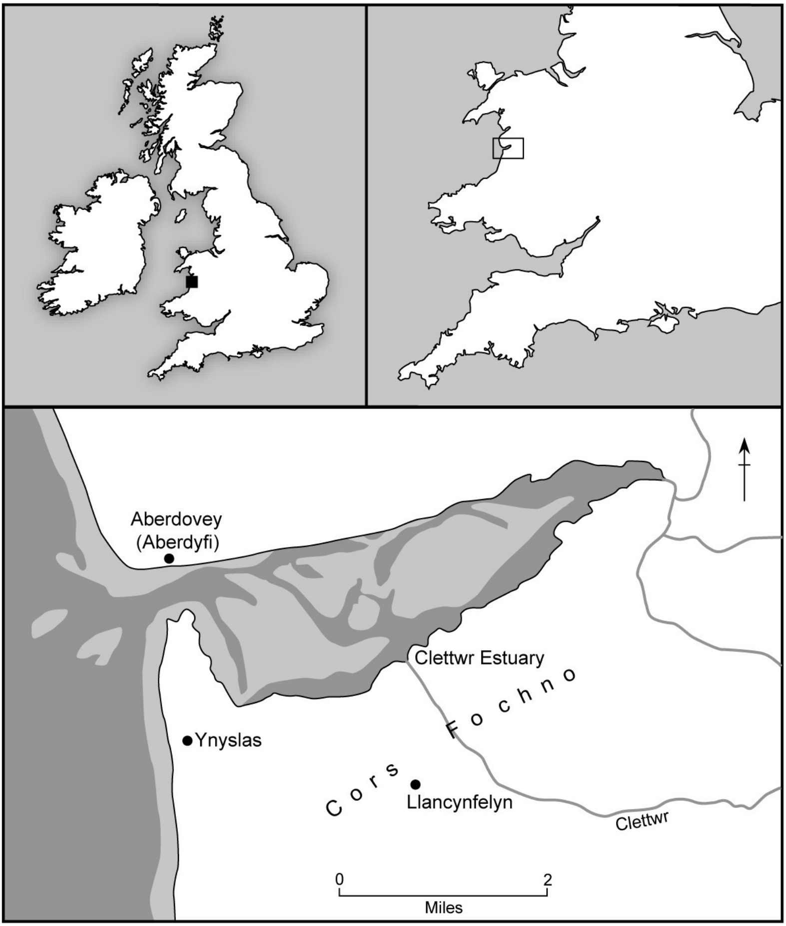

Figure 1. River Clettwr Estuary.

The assemblages are dominated by species found with *Carex* spp., the chrysomelid, *Plateumaris discolor*, the Curculionidae, *Limnobaris t-album,* and *Thryogenes festucae,* and the Staphylinidae, *Lesteva punctata,* and *Lesteva heeri,* are all found on tussocky, sedge-dominated marshlands (Koch 1992; Menzies and Cox 1996; Tottenham, 1954). The monophagous curculionid, *Micrelus ericae*, which was found in the sample in relatively large numbers, feeds exclusively upon *Calluna vulgaris* (Koch, 1992). Also found in some abundance are coleoptera typical of decaying organic material such as reed and sedge litter, such as the orthoperid, *Corylophus cassidoides,* and the staphylinid, *Micropeplus porcatus* (Koch 1989; Tottenham, 1954). A species of note in this sample is the anthicid, *Anthicus gracilis*, currently extinct in the British Isles and found amongst vegetation and organic detritus in swamps and bogs (Koch 1989). The status of this species is currently listed as extinct from the British fauna and is considered a thermophilous taxon. The present ecological range taxon is central and south eastern Europe (Duff, 1993) and it has been recorded on a number of archaeological sites in the Somerset Levels by Girling (e.g. 1977, 1979a, 1979b) and the Severn Estuary (Paddock, 2002; Tetlow, unpublished).

In the lower samples, the aquatic and waterside component is small and limited to species of stagnant, standing water such as the hydrophilid, *Hydrobius fuscipes* and the dytiscid, *Hydroporus obscurus* (Hansen, 1987; Nilsson and Holmen, 1995). Subsequently, conditions become wetter and the aquatic component, which increases sharply, is dominated by taxa found in acidic waters. A further dytiscid, *Hydroporus obscurus,* is restricted to pools of stagnant, oligotrophic water with *Sphagnum* spp. (Nilsson and Holmen, 1995). Finally, in the uppermost samples, the aquatic component is virtually absent, suggesting a prolonged period of drier conditions.

Discussion

The insect assemblages from the Clettwr Estuary compare well with other forms of site-specific proxy evidence used to reconstruct palaeoenvironments in the estuary. At the base, insects and waterlogged plant suggest *Carex* spp. and *Juncus* spp. dominated vegetation, which gives way to a more heterogeneous mosaic of carices, *Eriophorum* spp. and *Calluna* spp. In the uppermost sample, the waterlogged plant remains provide the first conclusive evidence of raised bog formation in this part of the Dyfi Estuary *c*. 4650-4500 ^{14}C yrs BP. At the base of the profile, pollen data indicates environments are similar to those suggested by the insects and waterlogged plant. Subsequently, pollen evidence diverges and indicates a pattern of succession significantly different to that suggested by the insect assemblages. At a depth of 45cm there is a significant peak in *Alnus* pollen, suggesting a significant expansion of this taxa nearby, *c*. 5820 cal. BP (4900 ^{14}C years BP). The alder expansion recorded in the Clettwr monolith is asynchronous to a similar peak recorded by Hughes and Schulz (2001) in cores recovered from the confines of the modern bog. The alder peak from the Cors Fochno sequence occurs earlier, just prior to 6255 cal. BP (Hughes and Schulz, 2001).

With the exception of this relatively small inconsistency, vegetative succession in this part of the estuary corresponds well with that of the area occupied by the modern confines of Cors Fochno, but with one major difference. Vegetation change occurs along similar timescales. At *c*. 6500 cal. BP tussocks of *Carex paniculata* replace reedswamp and carr woodland dominated by *Alnus glutinosa* gives way equally rapidly to *Betula* spp. and *Phragmites australis*, with *Pinus sylvestris* eventually replacing *Betula* spp. This swift episode of vegetation change occurs between 6430-6135 cal. BP (Hughes and Schulz, 2001). Evidence from Cors Fochno itself also indicates an earlier phase of raised mire development *c*. 6100 cal BP (Hughes and Schulz, 2001); evidence for which is absent from the Clettwr palaeoecological evidence.

Shi and Lamb (1991) also suggest that the Dyfi Estuary was much larger during this period of development (6,500-3,500 BP). This now seems unlikely on the basis of this data, as vegetative succession at the site is clearly well established by *c*. 6180-5900 cal. BP, suggesting that the area of open water in the estuary was beginning to contract. Raised bog had begun to develop *c*. 6,100 cal. BP, virtually synchronously at both Borth and in the vicinity of the Clettwr. The development of alder dominated woodland at this site, also suggests that the waters of the Dyfi Estuary remained some distance away from the site. The submerged forest, which lies on the current surface of the peat and developed after 5310-4970 cal BP, is composed of over 75% alder with some oak and birch. This woodland is likely to be a relic of the marginal lagg fen that developed around the main body of the raised mire complex, when Cors Fochno was significantly bigger than its modern dimensions. Early analysis of coleopteran faunas from Llancynfelyn, combined with dendrochonological dating of a trackway at this site, indicates the bog persisted in this area as late as *c*. 1133AD (Nayling pers. comm.).

Conclusion

This small-scale study has provided a useful insight into the development of Cors Fochno outside the current limits of the modern bog and suggests episodes of divergent vegetation development throughout the estuary. It has shed valuable light on the complex mosaic of ecosystem development at the study site throughout later pre-history.

Acknowledgements

The authors would like to thank Mike Bailey for permission to work at this sensitive site. Professor Mike Walker for his assistance with both field work and comments on pollen analysis. Nigel Nayling, Astrid Caseldine and Kate Griffiths for their supervision of Ms. Hurst, Dr. David Smith for his supervision of Ms. Joliffe and Dr. Ben Gearey for his helpful comments regarding the preparation of this paper. This work was funded by the Pantyfedwen Fund and the Quaternary Research Fund.

References

Duff, A. D. (1993). *Beetles of Somerset*. Taunton: Somerset Archaeological and Natural History Society.

Girling, M. A. (1977). Fossil insect assemblages from Rowland's track. *Somerset Levels Papers*, 3, 51-60.

Girling, M. A. (1979a). The fossil insect assemblage from the Meare Lake Village. *Somerset Levels Papers*, 5, 25-32.

Girling, M. A. (1979b). The fossil insect assemblage from the Sweet Track. *Somerset Levels Papers*, 5, 84-92.

Girling, M. A. (1984). Investigations of a second insect assemblage from the Sweet Track. *Somerset Levels Papers*, 10, 78-91.

Godwin, H. and Newton, L. (1938). The submerged forest at Borth and Ynyslas, Cardiganshire. *New Phytologist*, 37, 425-454.

Hansen, M. (1987). *The Hydrophilidae (Coleoptera) of Fennoscandia and Denmark Volume 18 – Fauna Entomologyca Scandinavica*. Leiden: E. J. Brill/Scandinavian Science Press.

Hughes, P. and Schulz, J. (2001). The development of the Borth Bog (Cors Fochno) Mire System and the submerged forest beds at Ynyslas. In: Walker, M. J.C. and McCarroll, D. (eds.) *The Quaternary of West Wales*. Bethesda: Gwasg Ffrancon Press. 104-112.

Kenward, H. K., Hall, A.R. and Jones, A. K. G. (1980). A tested set of techniques for the extraction of plant and animal macrofossils from waterlogged archaeological deposits. *Science and Archaeology*, 22, 3-15.

Koch, K. (1989). *Die Kafer Mitteleuropas: Ökologie Band 2*. Krefeld: Goecke & Evers Verlag.

Koch, K. (1992). *Die Kafer Mitteleuropas: Ökologie Band 3*. Krefeld: Goecke & Evers Verlag.

Lucht, W. H. (1987). *Kie Käfer Mittleleuropas*. Krefeld: Goecke & Evers Verlag.

Nilsson, A. N. and Holmen, M. (1995). *The Aquatic Adephaga (Coleoptera) of Fennoscandia and Denmark II. Dytiscidae – Fauna Entomologyca Scandinavica*. Leiden: E. J. Brill.

Menzies, I. S. and Cox, M. L. (1996). Notes on the natural history, distribution and identification of British Reed Beetles. *British Journal of Natural History*, 9, 137-162.

Paddock, E. A. (2003). A Sub-fossil insect assemblage from the 'Fourth Peat', Redwick, Gwent *c*. 4910 – 2930 BP. *Archaeology in the Severn Estuary*, 13, 47-52.

Shi, Z. and Lamb, H. F. (1991). Post-glacial sedimentary evolution of a micro-tidal estuary, Dyfi Estuary, west Wales, UK. *Sedimentary Geology*, 73, 227-246.

Tottenham, C.E. (1954). *Coleoptera. Staphylinidae, Section (a) Piestinae to Euaesthetinae*. Handbooks for the identification of British Insects, IV, 8(a). London: Royal Entomological Society.

Tetlow, E. A. (2005). *The Palaeoentomology of the Coastal Woodlands and Saltmarshes of the Severn Estuary.* Unpublished PhD Thesis, The University of Birmingham.

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NEWRESEARCHERSAWARDSCHEME

GEOCHEMICAL EVOLUTION OF A SUITE OF LAKES IN THE BADAIN JARAN DESERT, NORTH-WEST CHINA

Background and Rationale

It has been clearly shown by An *et al*. (2000) that the strength of the East Asian monsoon has varied during the Holocene. However the magnitude of short time variability is unknown. An understanding of short term monsoonal variability is required if accurate predictions are to be made of how the monsoon system will alter in the future as a result of climate change. The modern day landward extent of the Asian summer monsoon straddles the Badain Jaran Desert, China (Figure 1). The desert consists of the highest stationary sand dunes in the world (Dong *et al*., 2004), between which are numerous groundwater fed lakes, the salinities of which vary between 1 and >350 g l^{-1} (Yang and Williams, 2003). Sediment records from closed basin lakes in arid regions are often excellent indicators of changes in effective moisture (the ratio of precipitation to evaporation) (e.g., Holmes *et al*., 1999; Jones *et al*., 2005).

A number of short sediment cores have been collected from lakes in the Badain Jaran Desert and the palaeolimnological record of the lakes will be reconstructed using a multiproxy approach. However, it is essential that the modern hydrological setting of the lakes is fully understood to support the interpretations of the sediment records. Fieldtrips to collect limnological samples (e.g., water samples, sediment cores, aquatic plants) took place in June 2005 and September 2006. The desert contains two suites of lakes, one is located in the south-east part of the desert where there are numerous shallow (<2 m deep) lakes, the salinities of which vary from around 1 g l^{-1} to 400 g l^{-1}. The northern suite of lakes are deeper (maximum depths >8 m), larger and with salinities of >80 g l^{-1}. Due to the different conditions of the two suites of lakes, they are considered separately.

Methods

Water samples were collected from lakes and springs. All samples were analysed for δD, $\delta^{18}O$ and $\delta^{13}C$ at the NERC Isotope Geoscience Facility. Cation concentrations (Mg, Ca, K and Na) were analysed at the NERC ICP-AES Facility, Royal Holloway University of London. Anion concentrations (Cl, SO_4 and NO_3) were determined by ion chromatography in Lanzhou University, China. Alkalinity concentrations (HCO_3, CO_3 and OH) were determined by titration against hydrochloric acid in the laboratory immediately after fieldwork.

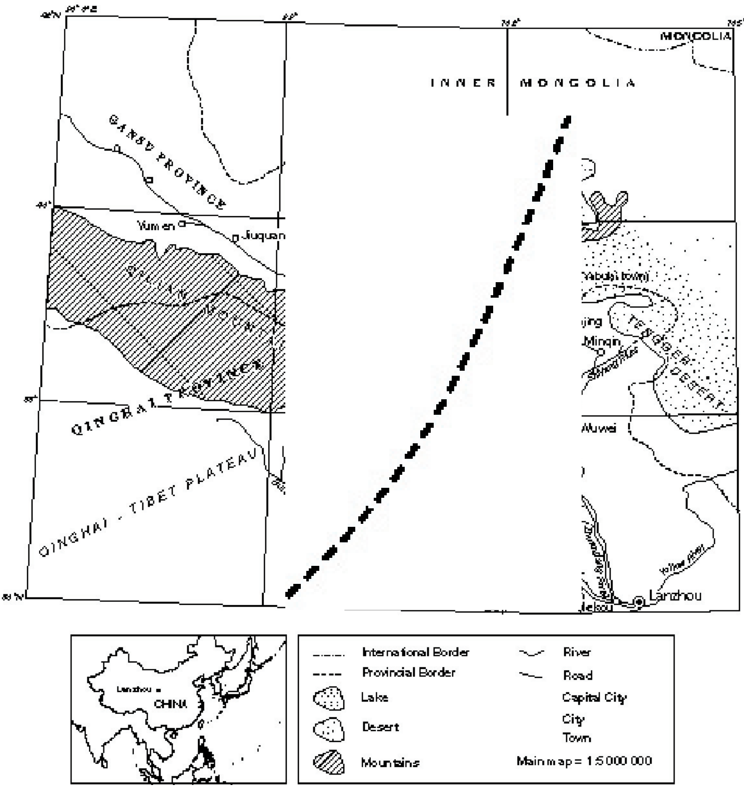

Figure 1. Location of the Badain Jaran Desert in north-west China. The dotted line on the main map shows the maximum landward penetration of the East Asian summer monsoon. Fieldwork was conducted around Lake

Results

Water salinity and $\delta^{18}O$ composition from closed lake basins are normally controlled by evaporation. During evaporation $H_2{}^{16}O$ is preferentially removed from the waterbody, leaving the lake water enriched in $H_2{}^{18}O$ (Craig, 1961), while the concentration of conservative ions (e.g., Cl, SO_4, Mg) builds up in the residual water as evaporation progresses (Eugster, 1980). If a relationship between salinity and $\delta^{18}O$ exists for the modern suite of lakes, it will be possible to reconstruct lake water relative evaporation using the $\delta^{18}O$ composition of fossil carbonates for the lake sediment cores.

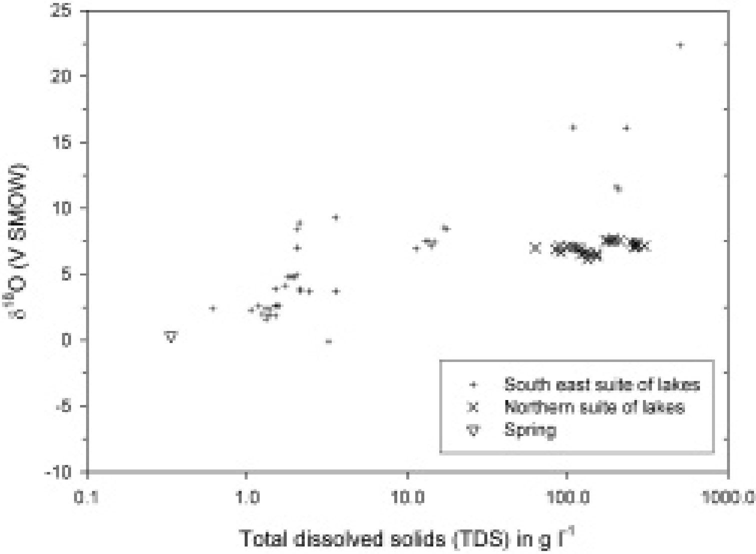

Figure 2. Total dissolved solids (TDS) against δ^{18}O from lakes in the Badain Jaran Desert. Data from both suites of lakes are shown. A spring which feds into one of the northern lakes is also shown for comparisons with the lake water data.

Figure 2 shows the total dissolved solids (TDS) against δ^{18}O composition of water samples collected from the northern and south-eastern suite of lakes from the Badain Jaran Desert. Data from the south-east suite of lakes show a clear relationship between lake water salinity and δ^{18}O composition. Reconstructions of δ^{18}O from subfossil carbonates from the lakes should, therefore, reflect variations in lakewater salinity linked to evaporation and inflow through time, providing that the spatial patterns provide a good model for temporal variation at any one site. Lower δ^{18}O from the carbonates will represent times of increased effective moisture, while higher δ^{18}O will occur during arid periods. This relationship between salinity and δ^{8}O is only present when considering data from lakes in the south-eastern suite. The northern suite of lakes show no relationship between δ^{18}O and salinity. The range in salinity of the northern lakes is 240 g l^{-1}, while δ^{18}O has a range of only 1.5‰. However, the northern lakes are controlled to some extent by evaporation, as shown by the evolution of lakewater salinity and δ^{18}O from the inflowing spring water to the lake water. Further work is required to understand the controls on δ^{18}O in the northern suite of lakes before any interpretations can be made of the palaeo- δ^{18}O records. Analysis of the elemental composition of water samples, together with other aspects of the limnology of the lakes studied is ongoing.

Significance

Research so far has shown the potential to reconstruct palaeosalinity from sediment records found in the Badain Jaran Desert and will allow reconstructions of effective moisture to be made for the Badain Jaran Desert, variations in which are likely to be linked to fluctuations in the location of the boundary of the East Asian summer monsoon. Due to the lack of short term palaeoclimatic records from this region any palaeoclimate from the Badain Jaran Desert will be extremely important in understanding short term variably in the monsoonal system.

Acknowledgements

We thank the QRA for a New Researchers Grant to AY that helped to fund the 2006 fieldtrip. The Royal Geographical Society, Gordon Foundation and The Universities' China Committee in London are also thanked for their finance support towards the fieldwork. Analytical funding is acknowledgement from NERC Isotope Geoscience Laboratory for stable isotope analysis (IP/858/0505) and NERC ICP facility for cation analysis (OSS/301/0905).

References

Craig, H. (1961). Isotopic variations in meteoric waters. *Science*, 133, 1702-1703.

Dong, Z., Wang, T. and Wang, X. (2004). Geomorphology of the megadunes in the Badain Jaran Desert. *Geomorphology*, 60, 191-203.

Eugster, H.P. (1980). Geochemistry of evaporitic lacustrine deposits. *Annual Review of Earth and Planetary Sciences*, 8, 35-63.

Holmes, J.A., Street-Perrott, F.A., Perrott, R.A., Stokes, S., Waller, M.P., Hunag, Y., Eglinton, G. and Ivanovich, M. (1999). Holocene landscape evolution of the Manga Grasslands, NE Nigeria : evidence from palaeolimnology and dune chronology. *Journal of the Geological Society*, 156, 357-368.

Jones, M.D., Leng, M.J., Roberts, C.N., Türkes, M. and Moyeed, R. (2005). A coupled calibration and modelling approach to the understanding of dry-land lake oxygen isotope records. *Journal of Paleolimnology*, 34, 391-411.

Yang, X. and Williams, M.A.J. (2003). The ion chemistry of lakes and late Holocene desiccation in the Badain Jaran Desert, Inner Mongolia, China. *Catena*, 51, 45-60.

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THE OXYGEN AND HYDROGEN ISOTOPIC COMPOSITION OF MODERN PRECIPITATION AND LAKE WATERS WITHIN MEXICO

Background and rationale

There are an increasing number of oxygen isotope (biogenic silica, ostracod, carbonate etc.) records from Mexico. However, limited monitoring of the modern isotopic composition of precipitation and lake systems exists. The International Atomic Energy Agency through their Global Network of Isotopes in Precipitation (GNIP) provide partial (and no longer active) monitoring data from Veracruz on the eastern coast of Mexico, and Chihuahua in northern Mexico. Data for the remainder of the country is interpolated from these stations. The geographical diversity of Mexico, with significantly varying ecosystems, weather regimes and altitudinal gradients, makes the current level of precipitation data limited in practicality. To interpret palaeoenvironmental records based on oxygen values, the controls on modern lake water and precipitation isotopic composition must be understood. Support from the QRA enabled sampling of lake waters across central Mexico during the dry season (April 2006), providing a comparison with wet season data from June 2005. The data will be added to previous isotope sampling undertaken by Davies and Metcalfe in 2001 (Leng *et al*., 2005) and by Jones and Metcalfe in 2004. This study will therefore establish a database of the isotope values of modern waters in Mexico, which can then be applied within future Quaternary Research.

Results and discussion

Figure 1 illustrates the results of sampling of the modern isotopic composition of Mexican lakes and precipitation. Precipitation values lie between –22.76 and –0.8‰ for $\delta^{18}O$ and –172.2 and +2.8‰ for δD. Lake water values lie between –10.52 and +3.1‰ for $\delta^{18}O$ and –75.4 and +3.0‰ for δD. Values are in relation to Vienna Standard Mean Ocean Water, and analytical precision is *c*.0.05‰ for $\delta^{18}O$ and 2.0‰ for δD. The plotted global meteoric water line (GMWL) is based on a statistical relationship between the covariance of oxygen and deuterium within annual precipitation ($\delta D = 8\ \delta^{18}O + 10$ (Craig, 1961)) around the globe.

Lake waters plot along a local evaporation line (LEL) separate to the GMWL. A variety of lakes are included within the data set ranging from freshwater spring fed lakes (e.g Zacapu, -9.9‰ $\delta^{18}O$ and –70.1‰ δD) to highly evaporated seasonally dry lakes (e.g Sayula, +2‰ $\delta^{18}O$ and –9.2‰ δD). Lake waters which plot on or alongside the GMWL are isotopically similar to precipitation, indicating a small residence time of waters within the lake. Lakes which plot

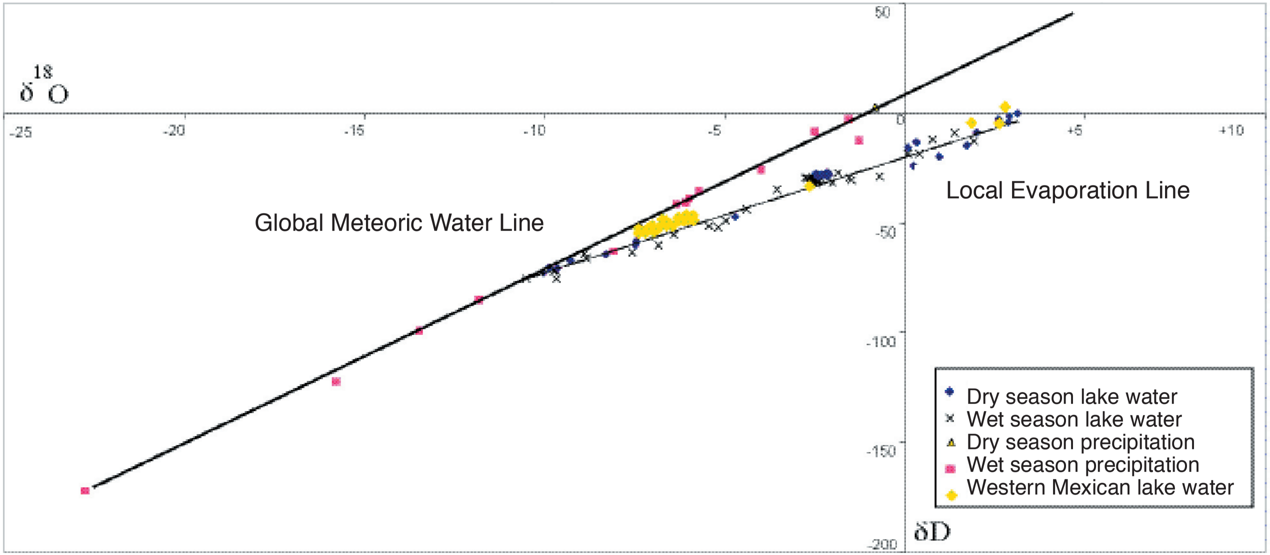

Figure 1. Isotopic composition of Mexican waters

along the LEL have undergone kinetic fractionation and evaporation has caused them to become more enriched in heavier isotopes. The kinetic fractionation of oxygen exceeds that of deuterium causing the divergence from the GMWL (Leng and Marshall, 2004). The position of a lake along the LEL establishes levels of relative evaporation between lake systems (Leng *et al*., 2005). The intercept of the LEL and GMWL lies at *c*.-10‰ δ^{18}O suggesting that the GNIP figure of 6‰ δ^{18}O for central Mexico may be questionable as an estimate of mean weighted precipitation (Leng et al, 2005).

Figure 1 illustrates how whilst some variation occurs on intra-annual scales, it is of a minor scale when compared to inter-lake differences (e.g Lago de Zirahuén changes from -2.3 to -2.1‰ δ^{18}O from wet to dry season, and –30 to –28‰ dD as lake waters become more concentrated). A shift along the LEL is observed rather than away from the LEL, suggesting evaporation is modifying the signal, as opposed to factors such as a change in source air mass. Variation in precipitation values are primarily a function of altitudinal effects, which can reach 2.1‰ δ^{18}O per km (Cortes and Durazo, 2001).

Highlighted on Figure 1 are lakes situated within Western Mexico under a possible Pacific derived moisture regime. Whilst it could be argued they plot above the LEL due to variations between Pacific and Gulf of Mexico moisture sources, more work is required within the Pacific region to confirm this, and especially due to the variation seen amongst other lakes away from the LEL, despite being within areas of Gulf sourced precipitation.

The establishment of this dataset allows inferences into the controls on the isotopic composition of a particular lake, an estimation of evaporation and information as to issues such as groundwater inflows. Open lakes with a low residence time will plot close to the GMWL as will lakes with a significant groundwater input. Closed lakes and evaporated open systems will plot further along the LEL. The similarity between plotted lake and precipitation values suggests that the Gulf of Mexico controls precipitation within the region, and that variations caused by the summer Monsoon are minimal, with negligible Pacific incursions across Mexico during the period of study.

Acknowledgements

We wish to thank the QRA New Researchers Award (to BA) for their support. BA is funded by a University of Wales, Aberystwyth, Studentship, and initial fieldwork was supported by the Dudley Stamp trust. Thanks to Matt Jones and Isabel Israde for field assistance and Carol Arrowsmith for laboratory support.

References

Cortes, A. and Durazo, J. (2001). Tendencia del oxigeno-18 en la precipitation del centro de Mexico. *Ingenieria hidraulica en Mexico,* 16, 93-102.

Craig, H. (1961). Isotopic variations in meteoric waters. *Science,* 133, 1702-1703.

Leng, M.J. and Marshall, J.D. (2004). Palaeoclimate interpretation of stable isotope data from lake sediments. *Quaternary Science Reviews,* 23, 811-831.

Leng, M.J., Metcalfe, S.E. and Davies, S.J. (2005). Investigating Late Holocene climate variability in central Mexico using carbon isotope ratios in organic materials and oxygen isotope ratios from diatom silica within lacustrine sediments. *Journal of Paleolimnology,* 34, 413-341.

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DENDROCLIMATOLOGY ON *JUNIPERUS PROCERA* IN THE UPPER BLUE NILE AND TEKEZE BASIN, ETHIOPIA

Background and rationale

The people of Ethiopia, Egypt and Sudan are strongly dependent on rainfall over the Northwest Ethiopian Highlands and subsequent River Nile discharge for agriculture and electric power. Adequate water resources management is thus essential. This requires longer reliable discharge records (Sutcliffe and Lazenby, 1994).

Dendroclimatology can provide an opportunity to extend the records. However, due to the tropical climate in Ethiopia, only a few tree species produce annual rings. One of the species thought to do so is *Juniperus procera* End. (Conway *et al*., 1997: Conway *et al*., 1998; Couralet *et al*., 2005). Ring definition is however dependant on seasonality in rainfall. Previous research suggests that tree-ring width and hydrogen and carbon isotope ratios are strongly related to water availability and hence precipitation (Couralet *et al*., 2005; Farquhar *et al*., 1982; Krishnamurthy and Epstein, 1985).

Based on these findings *Juniperus procera* trees were sampled at eight sites in Northwest Ethiopia (see figure 1). The area generally receives one wet season each year, *i.e*., during the summer when monsoonal rains are prevalent. A short wet season may occur in winter and spring, especially at the southwest sites, but these rains often almost merge into the long wet season. Samples from these sites are cross-matched. Subsequently, the dating is tested using bomb radiocarbon dating, *i.e*., dating of tree rings after 1955 when atmospheric radiocarbon levels were hugely elevated due to the nuclear attacks on Japan (1945) and atmospheric testing of nuclear and hydrogen bombs (mostly until 1963), which enables highly accurate radiocarbon dating.

Results

Ten trees from one site have been cross-matched and the subsequent dating has been tested using radiocarbon dating. Cross-matching appeared possible, which suggests that the growth rings reflect an externally enforced periodicity. Stahle (1999) even suggested that cross-matching in itself proves the *annual* nature of the rings. However, bomb radiocarbon dating on one of the trees revealed ages, which were approximately half the expected age. This suggests that the rings reflect two wet seasons per year, even tough the separation of these two wet seasons is weak. *Juniperus procera* would then appear to be highly sensitive to slight variations in rainfall, which complicates the building of a dated chronology, as the dynamics of climate are such that simply assigning two rings per year is in conjunction with reality.

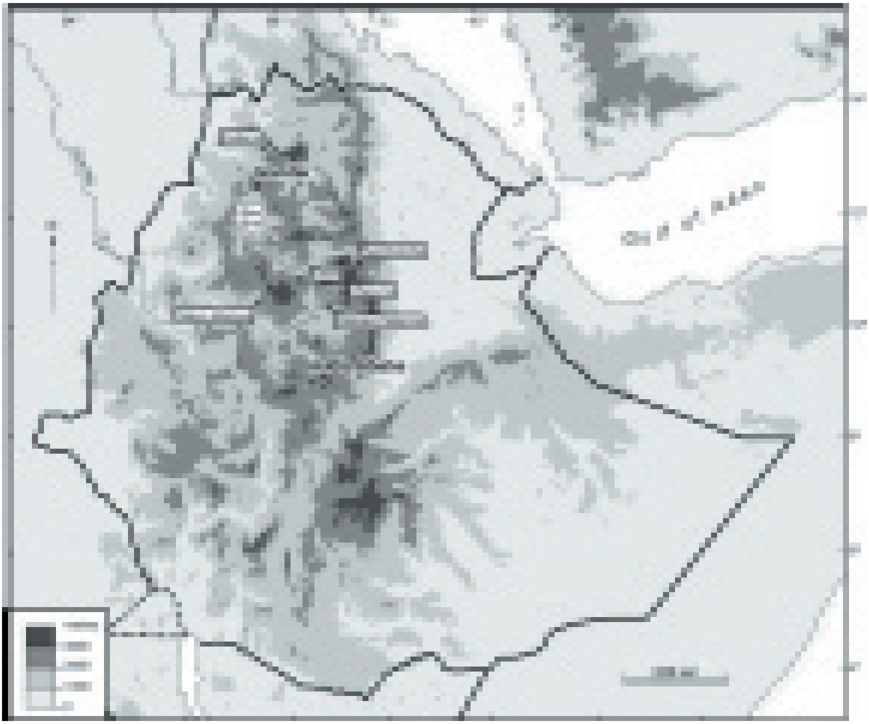

Figure 1. Map of Ethiopia showing the research sites (1-6, number 3 represents 3 sites). Nearby climate stations, capital Addis Ababa and a site of previous research (A (Sass-Klaassen, pers. comm.)) are also indicated.

Further research will focus on improving the understanding of the cause for ring formation in *Juniperus procera* and on the potential wood-anatomical difference between ring boundaries formed under the influence of the long and short dry season respectively, hence on the potential opportunity to yet date the rings. Besides, cross-matching and bomb radiocarbon dating of trees from sites significantly less affected by a short wet season will further clarify ring formation processes in *Juniperus procera* and its potential for dendrochronology.

Significance

The results are highly significant for tropical dendrochronology and for Ethiopian dendrochronology in particular. It has undermined Stahle's (1999) hopeful suggestion that cross-matching indicates annual rings and therefore provides a useful warning for dendrochronologists working in the tropics. On the other hand the intra-annual nature of the growth rings may provide an opportunity to study intra-annual environmental processes in a way impossible in temperate regions. The basis of Ethiopian dendrochronology has clearly been widened and provides both challenges and opportunities to improve the understanding of a climate system on which millions of people are extremely dependent.

Acknowledgements

The QRA is gratefully acknowledged for contributing to the fieldwork costs. This also applies to other funding organisations. Multiple Ethiopian governmental offices and the Ethiopian Orthodox Church are gratefully acknowledged for their support and kind permission to work at the different research sites. I would like to thank all who have supported the fieldwork and research in person. Special thanks I owe to Mr. Tesfaye Ayalew for excellent driving to the research sites and invaluable help in the field.

References

Conway, D., Brooks, N., Briffa, K.R., Desta, Sherrew, Merin, P.D. and Jones, P.D. (1997). *Exploring the potential for dendroclimatic analysis in Northern Ethiopia*. Final Report Natural Environment Research Council (NERC), Climate Research Unit, University of East Anglia.

Conway, D., Brooks, N., Briffa, K.R. and Merrin, P.D. (1998). Historical climatology and dendroclimatology in the Blue Nile River basin, Northern Ethiopia. In: Servat, E. Hughes, D., Fritsch, J.M. and Hulme, M. (Eds). *Water resources variability in Africa during the XXth century. Proc. Abidjan '98 Conference*. IAHS Publications, 252, 243-251.

Couralet, C., Sass-Klaassen, U., Sterck, F., Bekele, T. and Zuidema, P.A. (2005). Combining dendrochronology and matrix modelling in demographic studies: an evaluation for Juniperus procera in Ethiopia. *Forest Ecology and Management*, 216, 317-330.

Farquhar, G.D., O'Leary, M.H. and Berry, J.A. (1982). On the relationship between carbon isotope discrimination and the intercellular carbon dioxide concentration in leaves. *Australian Journal of Plant Physiology*, 9, 121-137.

Krishnamurthy, R.V. and Epstein, S. (1985). Tree ring D.H ratio from Kenya, East Africa, and its palaeoclimatic significance. *Nature*, 317, 160-162.

Stahle, D.W. (1999). Useful strategies for the development of tropical tree-ring chronologies. *IAWA Journal*, 20(3), 249-253.

Sutcliffe, J. and Lazenby, J. (1994). Hydrological data requirements for planning Nile management. In: Howell, P.O. and Allan, J.A. (eds.). *ß*. Cambridge University Press, 163-192.

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PALYNOLOGICAL CHARACTERISATION OF AMAZONIAN RAINFOREST COMMUNITIES IN THE NOEL KEMPFF MERCADO NATIONAL PARK, BOLIVIA

Background and Rationale

There is an urgent need to improve the interpretation of Amazonian fossil pollen records in order to better understand Quaternary vegetation dynamics in the Amazon Basin. The resolution of the long-standing debate on the extent of the Amazonian Rainforest during the Last Glacial Maximum (Haffer, 1969; Colinvaux *et al*., 1996; Pennington *et al*., 2000) is strongly dependent on sound understanding of fossil pollen records. Unfortunately, considerable uncertainty and speculation has arisen regarding the interpretation of these records (Mayle *et al*., 2004). Ecological inferences derived from fossil pollen assemblages are very simplistic and ignore the structural and floristic complexities of Amazonian forests and savannahs. Determining the characteristic pollen-rain signatures of different Amazonian plant communities is one way in which progress can be made within this field of enquiry. Interpretations of fossil records may then be made on the basis of phytosociological changes through time, rather than just on changes in the relative abundance of one or two taxa.

In order to improve the interpretation of Neotropical fossil pollen records within Noel Kempff Mercado National Park (NKMNP), Northeast Bolivia, we aim to characterise and differentiate four rainforest communities (*terra firme* evergreen, evergreen liana, seasonally-inundated and riverine forests) using pollen-rain assemblages obtained from a series of traps situated in each community. To test for similarity between pollen trap and lake surface samples, the data will then be compared with fossil pollen spectra from core-top samples of nearby lakes Laguna Chaplin and Laguna Bella Vista, and from a suite of lakes surrounded by rainforest in the Beni Basin, Northern Bolivia. The fieldwork associated with obtaining these surface sediment samples was supported by the QRA New Research Workers Award Scheme and performed in July and August 2006.

The principal field aims were:

- To collect surface sediment pollen samples from a suite of lowland Neotropical lakes within rainforest communities of the Beni Basin.
- To collect pollen from plant species not yet represented in the Neotropical reference collection held at the Institute of Geography, Edinburgh University.
- To gain experience in tropical plant identification and a better ecological understanding of Neotropical plant communities under the instruction of Botanists of the Natural History Museum of Santa Cruz in Bolivia.

Results and Significance

Research on the surface samples obtained from five lakes surrounded by rainforest communities within the Beni Basin (14º59'; 65º40') is ongoing. Lakes successfully cored included: Laguna Isirere, Beni Oxbow 1, Laguna Huachi, Laguna Puente de Ibare, and Laguna Loma Suarez.

Preliminary results of pollen rain data obtained from rainforest communities within the NKMNP suggest that they can be differentiated by their pollen spectra, which has implications for the interpretation of the "rainforest signal" lodged in many Amazonian fossil pollen records. These include key sites such as Laguna Chaplin and Bella Vista (Mayle *et al.*, 2004), the Amazon Fan (Haberle and Maslin, 2000), and Lake Pata in central Amazonia (Colinvaux *et al.*, 1996).

The analysis of modern reference pollen collected from the NKMNP in June 2006 indicates that we are able to distinguish key pollen types of the mulberry (Moraceae) and nettle (Urticaceae) families. Moraceae, one of the most abundant and ecologically important families growing in tropical rainforests of Central and Southern America, has hitherto only been identified to the family taxonomic level and grouped with Urticaceae in fossil pollen diagrams. Many of these pollen types are indicator species, such as *Maquira coriacea*, which is restricted to varzea (floodplain) forests throughout the Amazon Basin. Our ability to distinguish indicator taxa of the Moraceae family may help resolve much of the controversy surrounding the interpretation of key fossil pollen sites across the Amazon Basin (Colinvaux and De Oliveira, 2000; Pennington *et al.*, 2000; Bush *et al.*, 2004). Research is ongoing.

Acknowledgements

The author would like to thank the Quaternary Research Association for their financial support. Thanks are also extended to the Davis Expedition Fund at Edinburgh University and to my fieldwork colleagues Bronwen Whitney, Huw Jones, Ezequiel Chaves, Vladimir and Francis Mayle whose invaluable hard work and determination are much appreciated.

References

Bush, M.B., de Oliveira, P.E., Colinvaux, P.A., Miller, M.C. and Moreno, J.E. (2004). Amazonian paleoecological histories: one hill, three watersheds. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 214, 359-393.

Colinvaux, P.A. and de Oliveira, P.E. (2000). Palaeoecology and climate of the Amazon basin during the last glacial cycle. *Journal of Quaternary Science*, 166, 51-63.

Colinvaux, P.A., De Oliveira, P.E., Moreno, J.E., Miller, M.C. and Bush, M.B. (1996). A long pollen record from lowland Amazonia: forest and cooling in glacial times. *Science*, 274, 85-88.

Haberle, S.G. and Maslin, M.A. (1999). Late Quaternary vegetation and climate change in the Amazon basin based on a 50,000 year pollen record from the Amazon Fan, ODP site 932. *Quaternary Research*, 51, 27-38.

Haffer, J. (1969). Speciation in Amazonian forest birds. *Science*, 165, 131-137.

Mayle, F.E., Beerling, D.J., Gosling, W.D., and Bush, M.B. (2004). Responses of Amazonian ecosystems to climatic and atmospheric carbon dioxide changes since the last glacial maximum. *Philosophical Transactions of the Royal Society London B*, 359, 499-514.

Pennington, R.T., Prado, D.E. and Pendry, C.A. (2000). Neotropical seasonally dry forests and Quaternary vegetation changes. *Journal of Biogeography*, 27, 261-273.

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REVIEWS

THE LAST GLACIAL TERMINATION IN NORTHERN IRELAND

Marshall McCabe and Paul Dunlop

Geological Survey of Northern Ireland, 2006, ISBN 0-85272-529-9

With increasing interest in the anatomy of the Late Devensian British-Irish ice sheet in recent years, as demonstrated in the recent very successful QRA meeting in St Andrews, this book, which draws upon a wealth of new and recently published research, is most timely. Written in a clear and often forthright style, and with a useful glossary of terms, it is plainly intended for a wide readership. Accompanied by detailed Ordnance Survey maps of the locations discussed and by many diagrams and photographs, all in colour, it is both readable and informative.

The book begins with five short chapters addressing the basic pattern and timing of the Late Devensian ice sheet in Northern Ireland and adjacent areas, followed by a lengthy chapter describing and discussing the evidence from thirteen critical sites. It concludes with a chapter integrating and synthesising the evidence outlined and discussed. Site maps, references and a glossary complete the volume. Thus outlined, the book is effectively a field guide to critical Late Devensian sites in Northern Ireland which enable events which characterised the last glacial termination in the area to be outlined.

Chapter 1 introduces the scope of the book, briefly outlining the historical background to present day research on the subject. It reviews the postulated pattern of glaciation in the area and adjacent areas, together with the nature of the evidence for ice sheet decay, and lists the radiocarbon dates which form the basis for the sequence of events identified later in the volume. Chapter 2 briefly addresses the nature of the "Irish Sea Drifts", drawing attention to the nature of their foraminiferal assemblages, given that the dating of monospecific samples of the foram *Elphidium clavatum* form the basis for many of the interpretations which follow in later chapters. Chapter 3 outlines previous research methodologies used in the key area of the Irish Sea Basin, while Chapter 4 outlines an event stratigraphy for the Irish Sea Basin, rejecting the widely held view, as articulated, for example, in a recent issue of *Quaternary Newsletter*, that a terrestrial glaciation produced a moraine in the Scilly Isles. Chapter 5, which in a sense is the concluding chapter of the first five, outlines the authors' view on the timing and anatomy of the deglacial events in the northern Irish Sea Basin.

The main body of the book is contained in Chapter 6, which examines, site by site, the evidence for glaciation and deglaciation in the Late Devensian in Northern Ireland. The sites, located on Ordnance Survey map extracts placed at the end of the book, are described in detail, with excellent illustrative photographs and section drawings. This chapter reflects the authors' detailed field knowledge of the locations concerned. A particularly strong point of this account is that for most locations the stratigraphies discussed are placed in their morphological context. All too often in so many accounts of Quaternary sites in the United Kingdom and Ireland at the present time, exposures are described in great detail but their morphological context is not. This account does not fall into this trap, and for that is most welcome. The author of this review suggests that the approach adopted in this book probably reflects an increasing maturity in Quaternary research in these islands, which should bode well for the future.

Reading the site descriptions, one is struck by the lack of detailed information on the extent and altitude of former shorelines. Such information, if obtained, would help to determine the patterns of glacio-isostatic uplift in the area, especially when combined with information from adjacent SW Scotland. The evidence for former relative sea levels provided in the site descriptions will no doubt ultimately form a basis for detailed altitude measurement, which should help answer current questions relating to ice loading.

The seventh and final chapter is an integration and synthesis, addressing issues such as the extent of the ice sheet, identifying two major readvances, emphasising the massive and final deglaciation, and identifying relative sea level changes. The concept of monotonic deglaciation is rejected and the effect of crustal redepression during ice advances examined.

This book is very clearly based upon detailed field work, undertaken largely by the authors themselves. The detailed information provided will form an important basis for understanding the Irish Quaternary. In some areas, the interpretations outlined run contrary to widely held views, so that it is both informative and controversial. The detail of the evidence and the quality of the work which underpins the interpretations ensure that as we seek to determine the anatomy and events marking the growth and decay of the Late Devensian British-Irish Ice Sheet, this book will both provide essential information and stimulate useful debate.

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Following the Solway West special sheet (*QN* 109, 58) the eastern sheet of this pair has now been published. It covers a large 25 km by 40 km area around Langholm extending southwards down the River Esk to Gretna, and across the Solway Firth to Carlisle and the area adjacent to the western end of Hadrian's wall along the Cumbrian coast. The glacial Tills and gravels along with many other deposits including the intertidal zone and numerous river terraces are subdivided into over forty clearly defined units. In addition, geomorphological features including glacial meltwater channels, glacial striae and drumlin crestlines have been added, thanks to a detailed partial resurvey aided by aerial photography. Once again a perspective view satellite image of the area with a varying scale is provided along with a series of interesting cross-sections along the route of the motorway either side of Gretna and the border between England and Scotland.

The Liverpool (96) sheet has been completely resurveyed and includes most of the Wirral peninsular and Dee estuary plus a portion of Flintshire in North Wales. While the superficial geology mainly consists of Till and associated glacial deposits, there are spreads of blown sand along the Irish Sea coast and a complex series of coastal zone deposits, including a buried channel linked to the River Mersey between Birkenhead and Wallasey. Given the industrial past of the area, extensive areas of artificially modified ground are clearly indicated, as is the slightly simplified bedrock geology beneath the extensive superficial deposits. In the offshore areas, apart from Till filling the channel near the mouth of the Mersey around Liverpool pierhead, seabed sediments are shown. While offshore bathymetric contours are shown, there is some confusion between the limited intertidal areas above Ordnance Datum and depths at or below this level. At over 9 m, the range of spring tides in the Mersey is not insignificant, and so these tidal levels should have been quoted - even if this information is omitted from some BGS coastal maps, when it should be standard.

The Aberaeron (177) sheet covers a tiny portion of land along the coast of Cardigan Bay. Unlike the other 1:50,000 maps in this review which in due course will all be described by Sheet Explanations (illustrated colour booklets with references, obtainable with the map in question for a combined price of £18), the Aberaeron map is too small. That said, in addition to both bedrock and bedrock and superficial deposits versions of the map, the margins have a number of 1:250,000 insert maps including offshore Quaternary geology, seabed sediments and a series of shallow seismic sections displayed as fence diagram.

The neighbouring Llangranog (194) sheet along the coast towards Cardigan covers a hitherto ignored portion of Mid-Wales which was last mapped around 150 years ago. With the support of a grant from the Welsh Assembly these sheets have been covered by an extensive survey. While the Llangranog sheet has an impressive range of 24 different types of superficial deposits, the main distinction is between Tills and other glacial material derived from Welsh and Irish Sea ice which is clearly denoted on the map with different letters for each source. This distribution and the extent of deposits from the pro-glacial Lake Teifi, is also shown on an insert map, along with a clear but quite complex schematic cross-section showing the relationships of different superficial deposits to each other, and a highly detailed colour digital elevation model of the district based on an advanced airborne radar survey.

To the east the Lampeter (195) sheet extends inland. The Afon Teifi flows towards the southwest diagonally across the sheet past Lampeter, and this valley is associated with a complex series of glaciofluvial sediments, in addition to small pockets of lacustrine material, occasional alluvial fans and undifferentiated river terrace deposits. Over much of the rest of the sheet Till and to some extent glacial deposits lie in pockets which in many cases mask zones of underlying faulting. In the margins there is also a 1:150,000 insert colour digital elevation model of the area. Without a smaller sketch map or annotation, this is slightly intriguing as the caption suggests it is possible to distinguish areas which have been exposed to more extensive peri-glacial weathering after the early withdrawal of the Devensian ice from the south of this district.

The Ipswich (207) sheet in southern East Anglia has been completely remapped, so that the Kesgrave sand and gravel have been clearly separated from later Anglian glaciofluvial deposits, while Lowestoft Till blankets the higher ground over much of the district. River terrace deposits remain undifferentiated along the River Gipping and River Orwell which forms its lower tidal reaches where the low tide line has been clearly picked out with a blue line. As is the case with maps in East Anglia, the Crag formations are part of the bedrock as they are lithified, rather than being classified as superficial deposits. However, many consider the base of the Pleistocene to be 2·6 Ma, and some recent BGS publications have placed the Crag in the Quaternary rather than the Pliocene on this map. More significantly, unlike the previous edition, the bedrock insert map does not show the Palaeogene and Chalk subcrop pattern beneath the Crag, when quite clearly from the boundaries beneath the superficial deposits this has been completely revised.

The latest edition of the North London (256) sheet has a more extensive classification of areas with artificially modified ground. In addition a clear stippling effect has been added to indicate quite large areas on the London Clay with Head propensity where it is mostly likely to be covered by a veneer of Head deposits. This has been deduced from digital slope analysis confirmed by borehole data and is not verified by fieldwork and mapping in the traditional sense. Furthermore, an insert map of areas with the greatest potential for slope instability added in the form of a shaded relief image.

The Brighton and Worthing (318/333) and Lewes and Eastbourne (319/334) are adjacent maps which both combine coastal sheets to improved coverage. In both cases only the Chalk outcrop has been recently remapped and reclassified with added structural details, so it is now clear that valleys intersecting the coast at Brighton and Cuckmere Haven both formed along local faults. Apart from being more clearly printed than the old editions, the superficial deposits have been redefined with updated terminology and the coverage of artificially modified ground extended.

Finally, in Northern Ireland the Maghera (19) sheet west of Ballymena is divided into counties Londonderry and Antrim by the River Bann flowing northwards from Lough Neagh. As the cartographic style is slightly different, the map clearly emphasises the pattern of glacial drumlins as dark blue patches, often with marked crestlines, resting on quite extensive spreads of light blue Till. Eskers, kettleholes and glacial meltwater channels are also shown. Patches of different glaciofluvial deposits, especially parallel to the River Bann, are marked in pink tones quite similar but distinct from the lower basalt formation that pokes through the superficial cover in many places. Also, along the River Bann and south of Maghera in particular, there are quite extensive areas of peat and lacustrine deposits representing former post-glacial lake levels.

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DOCTOR OF SCIENCE

SCIENCE OF COAST AND SEA-LEVEL CHANGE

Michael John Tooley (Doctor of Science)

Michael Tooley was awarded a DSc from the University of Lancaster on December 13th, 2006 for his work on coastal and sea-level change. His long and distinguished career of research in Quaternary Science began with an undergraduate degree in Geography from Birmingham University in 1965, and after a year's Fulbright Scholarship at Columbia University, New York, he returned to the United Kingdom in 1966 to undertake a PhD at Lancaster University on Sea-Level changes in North-West England during the Flandrian Stage, under the supervision of Professor Frank Oldfield. This seminal work was later published as a book in 1978 by the Clarendon Press, Oxford. In 1969, he was appointed to a lectureship in Durham University, and to a chair at Durham in 1986. He later joined St Andrews University in 1995 as Professor of Geography and later as Head of the School of Geography and Geology. In 2000 he was appointed to a chair at Kingston University.

Michael Tooley's work largely centres around sea-level change in the late Quaternary, and particularly the Holocene. He is responsible for having refined and developed methodologies for studying the record of sea-level change in a wide variety of environments, notably employing stratigraphic and microfossil analyses, and following the inaugural meeting of IGCP 61 at the Geological Survey of the Netherlands in 1974 established the Durham University sea-level database, now widely used in sea-level reconstructions and earth rheology investigations. He entered the fray of discussion on the nature of the Holocene sea-level rise following the work of Fairbridge and Jelgersma, in the late 1960s, and is widely known for his work on the Lancashire coast, where his interpretation of a fluctuating relative sea level is widely recognised. However, he has also contributed to understanding of the sea level record in Scotland, Brazil, India, Bangladesh and the Maldives. His work has also included study of the rates of Holocene sea-level rise in NW Europe related to climatic change. His former students include Professors Shennan and Long and Dr. Zong at the University of Durham, Professor Devoy at University College Cork, Professor Islam at Chittagong University and Dr Haggart at Greenwich University. His work on sea-level change has led to involvement in INQUA as Secretary and later President of the Shorelines Commission and in IGCP as UK national representative of IGCP 61 and IGCP 200.

ABSTRACTS

SUBGLACIAL TILL – THE 'UPWARDLY MOBILE' SEDIMENT?

Mark Tarplee (Doctor of Philosophy)

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The recognition that subglacial entrainment, transport and deposition/emplacement processes predominantly occur within a deforming glacier bed has elicited a requirement for an assessment of erratic plume development models. A 93 km^2 area around the Tynagh mineral deposit, south-east County Galway, Ireland was selected in which to undertake the evaluation. The mineral deposit was discovered through soil geochemical surveys that revealed distinctive Pb, Cu, Zn anomalies extending eastwards beyond the margins of the orebody subcrop. Till sampling revealed the presence of a 4.5 km^2 erratic plume, the form of which concurs with 'general erratic train morphology'. However, detailed, three-dimensional, multi-scale sedimentological, geochemical and micromorphological analyses have revealed that a number of erratic plume 'characteristics' are misrepresentative, a product of insufficiently detailed morphology mapping techniques.

The Tynagh erratic plume is a product of sediment dispersal processes associated with deformation of a subglacial sediment layer. Ephemeral rotational and shear structures developed in response to applied shear stress, entraining orebody material at the base of the till, transporting it predominantly down-glacier, though also dispersing particles efficiently throughout the sediment layer. Incorporation and diffusion of metal poor sediment down-glacier of the subcrop source diluted the erratic content from the base upwards, creating the illusion of a rising plume. Fine-fraction erratic plumes reflect the last deformational phase to have reworked the whole sediment package and any subsequent, lesser phases, which may have produced a palimpsest form.

An updated idealised model is presented incorporating these findings. Though based on the Tynagh erratic plume, it should facilitate the (re)evaluation of other erratic plumes for the purposes of both palaeoice-flow reconstruction and mineral exploration. However, erratic plume morphological investigations should be accompanied by detailed sedimentological analyses.

The Tynagh erratic plume and other, proximal palaeo-ice flow indicators, concur with the multi-dome ice sheet model of the Late Midlandian Irish ice sheet.

CAVE INCEPTION AND DEVELOPMENT IN CALEDONIDE METACARBONATE ROCKS

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This is the first comprehensive study of cave inception and development in metacarbonate rocks. The main study area is a 40000km^2 region in central Scandinavia that contains over 1000 individual metacarbonate outcrops, and has nearly 1000 recorded karst caves (with passage lengths up to 5.6km). The area, which was repeatedly glaciated in the late Cenozoic, comprises a suite of nappes in the Cambro–Silurian Caledonides, a paleic range of mountains with terranes presently occurring on both sides of the northern Atlantic. Information about the stripe karst and non-stripe karst outcrops and their contained caves was assembled into computer-based databases, enabling relationships between the internal attributes of the caves and their external geological and geomorphological environments to be analysed. A rather consistent pattern emerged. For example, karst hydrological system distances are invariably shorter than 3.5km, and cave passages are positioned randomly in a vertical dimension, whilst commonly remaining within 50m of the overlying surface. This consistency is suggestive that the relevant cave inception, development and removal processes operated at a regional scale, and over long timescales. A consequence of the *epigean* association of caves with the landscape is that cave development can only be understood in the context of the geomorphological evolution of the host region. A review of the latest knowledge of the inception and development of caves in sedimentary limestones concluded that the speleogenesis of the central Scandinavian caves cannot be explained by these ideas. Five new inter-related conceptual models are constructed to explain cave development in metacarbonate rocks in the various Caledonide terranes. These are:

1. The *tectonic inception model* - this shows that it is only open fracture routes, primarily created by the seismic shocks that accompany deglaciation, which can provide the opportunity for dissolution of metalimestone rocks that have negligible primary porosity.

2. The *external model of cave development* - this black-box approach reveals how the formation, development and destruction of the karst caves are related to the evolution of their local landscape. During the Pleistocene, these processes were dominated by the cycle of glaciation, leading to *cyclic speleogenesis*, and the development of ever-longer and deeper systems, where the maximum distance to the surface commonly remains within one-eighth of the extent of change in local relief.

3. The *hydrogeological model* - this demonstrates that the caves developed to their mapped dimensions in timescales compatible with the first two models, within the constraints imposed by the physics and chemistry of calcite dissolution and erosion, primarily in almost pure water. *Relict* caves were predominantly formed in phreatic conditions beneath active deglacial ice-dammed lakes, with asymmetric distributions on east- and west-facing slopes. *Mainly vadose* caves developed during the present interglacial, primarily vadose, conditions, with maximum dimensions determined by catchment area. *Combination* caves developed during both deglacial and interglacial stages. The cross-sections of phreatic passages obey a non-fractal distribution, because they enlarged at maximum rates in similar timescales. Phreatic cave entrances could be enlarged at high altitudes by freeze / thaw processes at the surface of ice-dammed lakes, and at low altitudes by marine activity during isostatic uplift.

4. The *internal static and dynamic model of cave development* - this white-box approach demonstrates that many caves have 'upside-down' morphology, with relict phreatic passages overlying a single, primarily vadose, streamway. Both types of passage are guided along inception surfaces that follow the structural geology and fractures of the carbonate outcrops. Dynamically, the caves developed in a 'Top-Down, Middle-Outwards' (TDMO) sequence that may have extended over several glacial cycles, and passages in the older *multi-cycle* caves were removed downwards and inwards by glacial erosion.

5. The *Caledonide model* - this shows that the same processes (with some refinements) applied to cave development in most of the other (non-central Scandinavian) Caledonide areas. The prime influences on cave dimensions were the thicknesses of the successive northern Atlantic glacial icesheets and the positions of the caves relative to deglacial ice-dammed lakes and to local topography. Other influences included contact metamorphism, proximity to major thrusts, and marine incursions. With knowledge of these influences for each area, mean cave dimensions can be predicted.

The thesis provides the opportunity for the five models to be extended, so that cave development in other glaciated metamorphic and *sedimentary* limestones can be better understood, and to be inverted, so that landscape evolution can be derived from cave data.

A RE-EVALUATION OF THE ORIGINS OF LATE QUATERNARY RAMPARTED DEPRESSIONS IN WALES

Neil Ross (Doctor of Philosophy)

School of Earth, Ocean and Planetary Sciences, Cardiff University.

This thesis describes the results of sedimentological and near-surface geophysical investigations of the internal structure of late Pleistocene permafrost and glacial ice-related 'ramparted depressions' in Wales. These data were used to evaluate the possible origins of these landforms, which have previously been interpreted as the remains of open system pingos or lithalsas (mineral palsas). Six sites were investigated: i) Hirwaun valley; ii) Llanio Fawr; iii) Crychell Moor; iv) Cledlyn valley; v) Cletwr valley; and vi) Llanpumsaint. Each site investigation is presented as an individual case study. The precise origins of these landforms remain uncertain. The density of landforms at all sites however is inconsistent with their interpretation as relict open system pingos. Some sites (Hirwaun valley and Llanio Fawr) are unequivocally glacial in origin, whilst others (e.g. Llanpumsaint) are most probably a type of relict periglacial ground-ice mound, although formation via the grounding of icebergs in a proglacial lake cannot be ruled out. Conversely, the ramparted depressions of the Cledlyn and Cletwr valleys probably formed as a result of the meltout of stagnating glacier ice, although permafrost-related origins are also possible. The investigations of relict landforms are complemented by geophysical investigations (ground penetrating radar and electrical resistivity) of active open system pingos from Svalbard. Data from both the relict and active landforms suggests that groundwater seepage through geological discontinuities is important for ground-ice mound formation, and that there is a continuum of ground-ice mounds, from features cored with lenses of segregation ice (e.g. palsas and lithalsas) to others cored with massive, injection ice (pingos). Transitional forms between these two extremes will contain a mixture of ground-ice types.

QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently c. 1,000) is open to all interested in the objectives of the Association. The annual subscription is £20 with reduced rates (£10) for students and unwaged members and an Institutional rate of £35.

The main meetings of the Association are the Annual Field Meeting, usually lasting 3–4 days, in April, and a 1 or 2 day Discussion Meeting at the beginning of January. Additionally, there are Short Field Meetings in May and/or September, while Short Study Courses on techniques used in Quaternary work are also occasionally held. The publications of the Association are the Quaternary Newsletter issued with the Association's Circular in February, June and October; the Journal of Quaternary Science published in association with Wiley, incorporating Quaternary Proceedings, with eight issues per year, the Field Guide Series and the Technical Guide Series.

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ISSN 0 143-2826